

NEW YORK INDUSTRIAL EXHIBITION.

SPECIAL REPORT

OF

SIR CHARLES LYELL.

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[When “Exhibited products” are not given separately, they are noticed under the several heads of “Economic products.”]

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SPECIAL REPORT

ON THE

GEOLOGICAL, TOPOGRAPHICAL, AND HYDROGRAPHICAL
DEPARTMENTS OF THE EXHIBITION.

Introductory Remarks.

HAVING been requested, when I visited New York as Commissioner in 1853, to report on the Geological Department of the Industrial Exhibition, I have endeavoured to discharge this duty as well as was in my power; but the object has been less fully accomplished than I could wish, owing partly to the delay experienced in the arrangement and display of the collections of mineral and mining products and of geological and geographical maps sent for exhibition. Explanations have already been offered in the General Report of the steps taken by me to overcome the difficulties presented by this delay; and mention has been made of the assistance liberally afforded me by several eminent men of science in the United States. I take this opportunity of repeating my acknowledgments, in particular, to my friend, Mr. James Hall, Geological Surveyor of the State of New York, for the assistance which he gave me, both during my visit and after my return to England. We had previously made, together, in the years 1841, 1846, and 1852, several exploring excursions over different parts of the United States, with a view of studying the geographical and geological features of the country. On the present occasion,

Professor Hall's more extensive acquaintance with the geology of the Western States, and his professional experience in all that relates to the economical applications of his science, have enabled me to complete a task which, without such aid, I could scarcely have undertaken.

CLASS I.—MINING AND MINERAL PRODUCTS.

The classification of objects in the New York Crystal Palace being essentially the same as that adopted in the London Exhibition of 1851, we have first to notice the objects of raw production, which belong to the department of Class I, entitled "Mining and Mineral Products." The New York Association for the Exhibition of the Industry of all Nations stated in their prospectus, that it was their wish so to arrange the objects belonging to this class in a separate space assigned to them, as to make them afford information similar to that derived from mineralogical and geological maps, with the additional advantage of having presented to the eye the specimens themselves derived from each mining and mineral region. These collections were also to be accompanied and illustrated by geological maps and sections and by mining plans. Such intention has been to a considerable extent carried into execution under the superintendence of Professor Silliman, jun. When we regard the immense territory of the United States, the incipient condition of many of the mining operations, and the difficulty of interesting parties immediately concerned therewith, we are more surprised at the extent and variety of objects presented, than disposed to dwell on deficiencies observable in the collections which have been brought together and arranged within a few months.

Mining Products.—The mining products which form the most prominent feature of the Exhibition consist of the different varieties of coal and metals, such as iron, lead, copper, zinc, and gold. The coal and iron-ores

are derived chiefly from the eastern or Alleghany coal-field; the lead, from limestone and other rocks of silurian age, as well as from the metamorphic formations; the zinc, from metamorphic rocks in New Jersey; and the copper, from the metamorphic regions in the eastern part of the United States, but chiefly from the sandstone and trap regions of Lake Superior, the age of which has until recently been a subject of great difference of opinion among eminent geologists.

Geological Maps and Surveys.—We may here properly mention the geological maps which have been published from time to time, since they give a general view of the several districts which have yielded the various substances used for manufactures, building, ornamental purposes, or agriculture. These maps consist partly of the results of surveys, published and unpublished, undertaken by different States and by the General Government; and partly of those of more general character, in which the geological information obtained during such public surveys, and other knowledge acquired by private exertions, have been set forth.

These maps, and the sections and plans accompanying them, were but meagrely represented in the Exhibition, but some of the more important ones, already in the hands of the public, may be alluded to in connection with the mineral products of the country, the geographical position of which will thus be more readily comprehended.

Within the last twenty years geological surveys have been commenced, and completed in eight of the States, viz., Massachusetts, Rhode Island, Connecticut, New Hampshire, New York, New Jersey, Delaware, and South Carolina. During the same period geological surveys have been ordered by legislative authority, and carried forward in a greater or less degree, in fifteen of the States, viz.: Maine, Vermont, Pennsylvania, Maryland, Virginia, North Carolina, Georgia, Alabama, Tennessee, Michigan, Ohio, Indiana, Illinois, and Missouri.

At the present time the surveys of Pennsylvania,*

* Renewed after a suspension of several years.

North Carolina,* Alabama, Illinois, Wisconsin, and Missouri are in progress. The others have been suspended after one or more reports of progress had been made: Of those States in which surveys are completed, we have geological maps; and in connection with the survey of Alabama, though still in progress, there is published in the first biennial Report a geological map of the State.

Various surveys and reconnaissances, which have been undertaken by the United States Government with other purposes as the main object, have nevertheless contributed to our knowledge of the geology of the regions over which they have passed. A geological survey of Oregon has recently, however, been instituted by the General Government; and similar surveys of Lake Superior and Chippewa Land Districts have been completed. The former, under the charge of Messrs. J. W. Foster and J. D. Whitney, published in 1851, has furnished us with a geological map of the southern shore of Lake Superior, and of all the northern peninsula of Michigan, and incidentally of some of the adjoining territory, affording a link which shows in a very satisfactory manner the connection between the eastern and western areas of the great silurian formation of the Northern States. The surveys of Dr. D. D. Owen in the Chippewa Land District, published in 1852, have furnished us with a geological map of Wisconsin, Minnesota, Iowa, and a part of Missouri.

Notwithstanding the incomplete condition of many of the surveys of the different States, we have from the reports of progress, and from other information obtained by individual enterprise, a very good general knowledge of the limits of the several geological formations throughout that part of the United States east of the Rocky Mountains, and to some extent also of the country west of this range. Of the geological maps which are the results of individual enterprise, or combining the results of public surveys and private investigations, may be mentioned a geological map of North Carolina, by Professor Mitchell, published in 1842; a geological map

* A geological survey of North Carolina was made many years since by Professor Olmstead, but we believe no map was published at that time. The present survey has been in progress two years.

of the Western States,* by Dr. D. D. Owen, published in the Quarterly Journal of the Geological Society of London, 1842; and a similar map, by Byram Lawrence, in 1842; a geological map of the Middle and Western States, by James Hall, published in the Geological Report of New York in 1843; a geological map of the United States and Canada, by Sir Charles Lyell, 1845; and of part of Canada and New York State, by Mr. W. E. Logan, in the Geological Society's Journal for 1852; a geological map of the United States and British Provinces, by Jules Marcou, and another by Professor Hitchcock, in 1853.

By consulting the Reports of the various States and their accompanying maps, as well as the more general maps here noticed, where this scattered information has been connected and arranged, we are able to refer to their respective geological formations all the materials presented in the Exhibition.

It is much to be regretted that during these geological surveys, a system of triangulation had not been adopted, by which means the topography and geology could have been accurately laid down at the same time. As an unavoidable consequence, the geological maps cannot present in detail the exact limits and variations of outline of the several geological formations, nor the physical features dependent on geological agencies.

GENERAL GEOLOGY AND PHYSICAL GEOGRAPHY.

Introduction.—The leading geographical and geological features of the United States exert, as in other countries, a powerful influence on the industrial occupations developed there, and on the resources of different portions of the Union. But it is in the vastness of this influence, and in the great extent of certain formations yielding particular products and devoted to particular industrial pursuits, that the United States present in many respects a different aspect from every other country of the globe. The immense and uninter-

* The Western States here spoken of are those situated on the western side of the Appalachian chain.

rupted areas of pre-eminently agricultural character are, for the most part, destitute of valuable mineral products, except limestone and ordinary architectural materials. Certain portions of the country are thus placed at great distances from the resources of manufacturing pursuits, and consequently precluded from their natural advantages. There are other areas, of vast extent, which combine great mineral wealth, and other conditions adapted for manufacturing enterprise, with an excellent soil. Again, there are areas of mineral production situated upon the extreme confines of the inhabited parts of the country; and others which remain untouched from their remote and inaccessible position. These, however, are gradually being added to the available resources of the nation, and are destined one day, by the rapid advance of new settlements, to be in the midst of a populous and wealthy country.

In the existing condition of a country like the United States, it would be impossible to present, in any Exhibition or any Report, more than an approximation to a sketch of its industrial resources. Mining operations are for the most part in their infancy, and in certain regions new mineral resources are constantly coming to light. Indeed, so long as vast tracts of country of great agricultural capacity remain unoccupied, and while the population continues sparse and labour dear, it cannot be expected that mining and manufacturing enterprises can be carried on to the extent which the wants of the country require. The lands of highest agricultural value will necessarily be occupied first, and those regions offering less inducements to the agriculturist will remain for a long time comparatively unknown.

Beyond the mining of coal and iron-ore, and, we may perhaps now add, copper and lead, the mining enterprises undertaken have been more the result of chance and speculation, than of any systematic effort to develop the mineral resources of the country; consequently, much of that part of the United States where we may look for mineral resources of value is very little known, beyond its general geological features, and a few attractive or accidentally discovered localities of mineral wealth.

The geological and mineralogical surveys have mostly had for their object the determination of the limits of geological formations, with a general indication of the contained minerals or metals of value. It has not been the province of the surveyors to examine each district with the detail essential to a determination of the existence of certain ores or minerals in workable quantities, except where these substances formed a prominent feature in the surface characters of the formation.

The private surveys undertaken with a view to mining operations have been generally limited to a particular locality or moderate area, and these reports do not often go beyond the immediate object of the investigation, viz., the present or prospective value of the tract under immediate examination.

In regard to the mining interests, beyond those of coal and iron, it may be said that the most valuable general information possessed is of a negative character. It is well ascertained that certain great areas, from the nature of the geological formations, are destitute of valuable mineral products. Theoretically, we are prepared to go further, and to say, that with the exception of a certain area comprising parts of Illinois, Wisconsin, and Iowa, where lead is known to exist, ores of gold, silver, copper, lead, zinc, and other metals cannot be sought for successfully beyond certain igneous or metamorphic formations, the limits and extent of which are ascertained.

We therefore know the areas within the limits of which mining operations must be carried on in future ; but the present state of these by no means gives an adequate idea of the future magnitude of this department of national industry. In a word, the yearly experience of the United States, and the advances of the nation in this direction, prove very conclusively the broad foundations of her mineral resources.

The physical and geological character of the Eastern* United States may be comprehended in a few sentences. From the north-eastern extremity, stretch-

* The Eastern States are those on the eastern side of the Appalachian chain.

ing south-westerly, nearly to the Gulf of Mexico, lies a belt of mountainous or elevated and more or less broken country, sometimes rising to the height of more than 6000 feet above the level of the sea. Throughout the whole extent it presents evidences of uplifting agencies, which have operated in lines parallel to the direction assumed by the mountain chains. This mountainous country occupies nearly the whole of New England, its numerous indentations affording excellent harbours along the coast. It crosses New York at the Highlands, and to the southward gradually recedes from the coast, leaving a widening belt of more recent formations between it and the Atlantic. The States are limited on the north mainly by the course of the St. Lawrence and the Great Lakes; we have, nevertheless, only to look a little beyond this limit to find a chain of mountains running parallel to the St. Lawrence as far as its source in Lake Ontario, and thence stretching westward, and, penetrating in a few places the geographical limits of the States, it extends, with few interruptions, to the Rocky Mountains. The latter chain has a general southward course, and reaches the southern limits of the United States at about the 105th degree of longitude. The great basin, or rather plain, bounded by these ranges of mountains, and opening to the southward on the Gulf of Mexico, is, with very limited exceptions, occupied by sedimentary strata in their normal condition, and presenting, for the greater part, only slight deviations from their original horizontal position. West of the great eastern or Appalachian chain, we have a wide area of the older formations, from the lowest sedimentary rock to the coal, inclusive. These formations reach, in their widest extent, from the valley of the Hudson to beyond Council Bluffs on the Missouri River, or over a space of twenty-four degrees of longitude. Further south their breadth is considerably reduced, and they finally reach their most southerly termination, as occupying a continuous area, in the northern part of Alabama. From north to south, these formations extend uninterruptedly over nearly fifteen degrees of latitude, or from the south shore of Lake Superior, in latitude $47^{\circ} 50'$, to below 33° of north latitude. Such is the

vast extent of the Palæozoic (or primary fossiliferous) formations in the United States, leaving out of view smaller areas not directly connected with this great plain. Of this immense territory, it is scarcely too much to say, that nearly one-half of the entire area is occupied by the coal-measures of the carboniferous period.

Flanking the Appalachian chain on the east, and forming a broad belt or plateau along the Atlantic coast and the Gulf of Mexico, we have the cretaceous and tertiary formations. These extend into Texas, thence, trending to the northward, they form a wide belt between the western limit of the palæozoic formations and the Rocky Mountains chain.

Such simply are the great geological features of this vast country, the details of which, however, would require many volumes to describe.

In the midst of the cretaceous formation in Texas is an isolated mountain of older igneous or metamorphic rocks, surrounded by those of palæozoic age (*vide* Dr. F. Roemer's "Cretaceous Formation of Texas"). In Arkansas there is a belt of similar character and of greater extent, near the junction of the palæozoic and cretaceous rocks; and again, in Missouri, we have, in the midst of silurian and carboniferous strata, mountains of the older metamorphic rocks.

It is within the limits above described, and from the geological formations indicated, that the industrial resources of the Eastern United States, both agricultural and mineral, are to be chiefly derived.

In viewing the mountain barrier which lies to the east of the great central and western plain, it must not be supposed that it is impenetrable except by difficult roads, or that the country lying to the west of it presents an unbroken monotony of surface. Nearly the whole extent of the northern frontier is occupied by a chain of great lakes, navigable for the largest steamers and other vessels, and presenting, within the United States alone, a line of coast of nearly 3,000 miles, exclusive of smaller bays and rivers which communicate with the same. The several outlets from these to the Atlantic render communication as easy between the remote inte-

rior regions and the coast as between equally distant maritime cities.

The western and central portions of this great area are traversed by navigable rivers, whose great outlet, by the Gulf of Mexico on the south, invites trade and commerce in that direction. Towards the north and east the waters of these rivers are connected by canals with those of the great lakes; and numerous railroads traverse the entire territory on the east of the Mississippi River, and will soon extend to the Rocky Mountains.

It will thus readily be seen, that in considering the industrial resources of a country of such vast extent, and which is still in its infancy, a juster idea of its capabilities will be formed by studying its leading physical and geological features, than by examining collections of its minerals and rocks in any place of exhibition. With this view it will be necessary to preface the special notice of raw mineral products, by a short sketch of the principal geological formations; noticing the characteristics of each, its geographical extent, and its products.

The geological formations of the United States, which either afford materials of use, or give character to the portions of country which they occupy, may be enumerated in the following order, omitting the minor sub-divisions described in detail in the Geological Reports of the various States :—

Alluvial and drift formations.

Tertiary.

Cretaceous.

Oolitic or liassic (jurassic).

New red sandstone (triassic?).

Coal measures.

Carboniferous limestone, with other rocks below the coal-bearing strata.

Old red sandstone, or Devonian formation.

Upper silurian.

Lower silurian.

Crystalline, or metamorphic rocks of the Appalachian chain, chiefly recognised as metamorphic rocks of Palæozoic age.

Older metamorphic or crystalline rocks.
Trappean rocks.

ALLUVIAL AND DRIFT FORMATIONS.

The superficial deposits referable to the Drift-period are almost universally distributed over the larger part of the United States. The presence of large boulders is usually regarded as indicative of this deposit; but these, in many instances, are absent, or not conspicuous, over large areas where the country is deeply covered with water-worn materials. In the mountainous regions the superficial deposit, lying next to the older rocks, is usually unstratified, and fragments of all sizes, more or less worn, lie confusedly mingled together; while, throughout a large part of the great plain west of the Alleghanies, this deposit is more or less regularly stratified, and the materials sorted. Everywhere, in fact, water-worn materials cover the surface of the older subjacent rocks. In all localities these older formations bear evidence of powerful erosive action, and whether in the northern portion of the United States, where boulders are frequent, or in the south, where the materials are less massive, the results are similar, and all seem referable to the same agency.

The various modifications which this deposit has subsequently undergone need not now detain us; since it is only in reference to the general character and economical relations that we are to treat of it.

As a general rule, obtaining over the Northern and Middle States of the Union, the character of this drift is dependent on the strata lying immediately beneath it, or a short distance north of the locality. Although conspicuous masses or boulders of northern rocks are found one or two hundred miles south of their origin, yet it is not to be supposed that any considerable proportion of the superficial mass has been derived from equally distant points. It is only along a few valleys or watercourses that large quantities of water-worn materials have been carried to the south. The area occupied by them is, therefore, small, compared to that which is occupied by materials derived from rocks

in close proximity. Were it otherwise, or were it true that the causes transporting these northern materials were as powerful as sometimes supposed, the influence of underlying geological formations could not be relied on for producing their legitimate results upon the soil above. Over comparatively small areas of mountainous countries, it is true, this disturbing influence can hardly be over-estimated; but in the general extent of the United States the soil corresponds in character with the nature of the rocks below. This superficial deposit, when found undisturbed and resting on the older rocks from which it has been derived, usually contains a large amount of coarse materials; subsequent changes, produced by water in more or less rapid motion, have modified the original condition, separating the coarser from the finer materials, and depositing each in regular layers, unmixed with the others. At a still later period small bodies of water, remaining in depressions of this formation, have given origin to a growth of vegetation, which in its decay has been preserved in the numerous swamps and marshes, together with the bones of animals, shells, and other fossil remains. There have been also incursions of the sea, and deposits of marine sand and clays, with organic forms of marine origin, mingling with the water-worn materials of the drift or superficial accumulations.

Economical Products from the Alluvial and Drift Formations.

Gold.—This metal, which is the only one of value occurring in the formations of this age, is derived from the destruction of certain auriferous metamorphic rocks. In the Eastern* United States the gold-bearing drift is derived from a series or group of sub-crystalline metamorphic rocks, which may be denominated newer metamorphic in contradistinction to the older system of metamorphic rocks, which will be described under that name in the present Report. This drift is co-extensive with the formation from which it is derived,

* See ante, p. 6, for explanation of Eastern States.

and is found from the northern limits of the United States in Vermont and New Hampshire, along the Green Mountain range, and passes through the southeastern part of New York, extending thence along the eastern flank of the Appalachian chain to Georgia and Alabama. This drift has proved productive of gold in considerable quantities in Georgia, South Carolina, North Carolina, and Virginia; but further north it has not been wrought for gold within the limits of the United States, although it has long attracted attention in the same direction in Canada, and a considerable quantity of gold has been obtained from washings on the Chaudière river. In California the gold-bearing drift or alluvium is derived from rocks of similar metamorphic character, and probably of the same age. These auriferous sands and gravels are very extensively distributed; the collections in the Exhibition showed samples of gold from nearly 200 different washings or localities in California alone.

Copper.—This metal, though occurring in the metallic form and in that of some of its ores in the drift, has never been found of economic value in this formation.

Iron Ore.—Magnetic iron-sand is a very general accompaniment of the drift in the vicinity of mountain ranges. It has not, however, been applied to economic uses. Bog-iron-ore is almost universal, though in quantities to be valuable only in comparatively few places. The hæmatite, so abundant along the base of the Alleghanies and in other localities is sometimes, it would appear, associated with clays of this formation. Specimens of these from various places were shown in the Exhibition.

Sands and Clays—Fit for the purposes of making bricks and coarse pottery, are widely and abundantly distributed; many millions of bricks are annually produced. Owing to the iron contained in the clay, they are usually of a reddish brown; but in Wisconsin, particularly in the vicinity of Milwaukee, the clay produces bricks of a drab or yellowish colour, which are so highly prized that they are transported many hundreds of miles.

Peat and Shell Marl, &c.—In a few districts of the

New England States peat is used for fuel to some extent; but generally very little use is made of it for that purpose in the United States. The peaty deposit or "muck" of many of the swamp lands is much valued as manure, together with shell-marl derived from the decomposition of the shells of existing species of mollusks. Sometimes alternating strata of muck and shell-marl occur in swamps of large magnitude. It consists of an aggregation of small shells with granular or pulverulent carbonate of lime, which is deposited from springs having their origin in limestone formations, or which have percolated the calcareous drift or alluvium, carrying thence the calcareous matter dissolved in the water. In some places where the drift contains an abundance of pebbles, they are used with cement for building walls, and even houses and other buildings. In many places, in consequence of the great depth of the drift and alluvial formation, or from it overlying shaly deposits, which afford no good building material, these large pebbles and boulders become of much importance to the inhabitants of the district.

Exhibition.—The specimens in the Exhibition from this formation consisted principally of native gold, from about two hundred different washing or localities in California, and a few from other places; a boulder of native copper from Wisconsin; bog-iron-ore; ochre; marl; soil, &c.

TERTIARY FORMATIONS.

The tertiary formations proper are of marine, estuary, and fresh-water origin; consisting of numerous argillaceous, arenaceous, and calcareous beds, and of various admixtures of the like materials. These strata, containing remains of numerous shells, corals, &c., land plants and animals and fresh-water shells, have a wide range in the United States. They commence at the north-eastern extremity of Maine, if we include the deposits in the valleys of Lake Champlain and the St. Lawrence, and, stretching south-westerly, become well defined south of New Jersey, thence extending south and south-west, they occupy a broad belt between the

Atlantic and the base of the mountain range. Still farther to the south and west the same formations continue to expand; and, trending westward past the southern extremity of the Highlands, spread out over the southern part of Georgia, Alabama, Mississippi, and a large part of Louisiana and Texas bordering the Gulf of Mexico. To the northward from Texas the tertiary formations extend along the base of the Rocky Mountains, forming a broad belt, flanked on both sides by the cretaceous rocks. The deposits of this age reach even to the sources of the Missouri, and spread out into the interminable wastes of that region known as the *Mauvaises Terres*.

West of the Rocky Mountains, and between that region and the Sierra Nevada, tertiary fossils have been collected by Captain Fremont and Captain Stansbury from widely separated localities, leaving no doubt of the existence of the formation on a large scale in that part of the continent. On the western coast the tertiary deposits are equally extensive and well developed, as we have learned from Dance and others (see United States Exploring Expedition: Geology by T. D. Dance); but the details have not been studied.

Economical Products of the Tertiary Formations.

Brown Hæmatite and Ochreous Iron Ore.—It has been long known that there occurs in the United States an almost continuous belt from Canada to Alabama, containing hæmatitic iron-ores, ochres, &c., and clays of a peculiar character. This ore has been regarded as an aqueous or oceanic deposit, and as having been derived from the subjacent strata through the agency of thermal springs. The discovery of a bed of brown-coal associated with the ores and clays has induced Professor Hitchcock to refer the whole to the Pliocene period; but the data for determining their precise geological age are as yet very incomplete.

The hæmatite is usually compact, fibrous, and stalactitic, and always more or less enveloped in clays of various colours. Throughout New England this formation lies at the western base of the Green Mountains,

and rests upon a metamorphic limestone, which is more or less associated with talcose or micaceous slate. From these beds the iron may have been derived, as it probably has been, by the action of thermal waters at the period of the deposition of the clays.

In Pennsylvania these ores occur in depressions or fissures in the unaltered limestones of the lower silurian period, but associated with or enveloped in clays; while farther to the south, however, the hæmatites of this character are associated with metamorphic strata.

This deposit is one of the most important sources of iron-ore, and the first worked in this country, furnishing an excellent material, and readily wrought. Specimens of the ore and of the manufactured iron were presented from Vermont, Massachusetts, New York, New Jersey, Connecticut, Pennsylvania, and Maryland.

Manganese.—Black oxide of manganese occurs in numerous localities, associated with the hæmatite above-mentioned. It occurs at Brandon and Bennington, Vermont, in large quantities. The black oxide of manganese exhibited from several southern localities is probably from this formation.

Fossil Fuel.—A bed of brown-coal associated with the hæmatite and fire-clays occurs at Brandon, Vermont, and is there used as fuel. Lignites are found in many localities. Specimens of tertiary coal have also been brought from the country west of the Rocky Mountains, and from the Pacific coast.

The only specimens exhibited at the Exhibition were from Brandon, Vermont.

Fire Clays and Porcelain Earth.—Kaolin, and various coloured clays, of greater or less purity, occur in this formation along the western base of the Green Mountains. They are mainly used in the manufacture of fire-bricks and the stronger kinds of pottery. The clays are pure white, yellowish from iron, and pink-coloured from manganese. Clays of similar character are known in several localities in New Jersey.

Another variety of clay, perhaps a little more recent in its origin, is, however, the most abundant in the State of New Jersey. It occurs in the neighbourhood of South Amboy, and is known as “potter’s clay:”

from this source are supplied many of the manufactories of "stone-ware" in the United States. It is associated with, or succeeded by beds of mottled clay and sand. Fire-bricks are also extensively manufactured from these beds.

Specimens were exhibited from Brandon, Vermont, and also some specimens of kaolin and fire-brick from New Garden, Pennsylvania.

Shelly Marls and Green Earth.—In New Jersey, Maryland, Virginia, and farther to the south, shelly marls, sometimes containing green-earth, but frequently without, are used by agriculturists for enriching the soil.

Building-materials.—In this formation, sand, clay, and brick-earth supply the want of good building-stones. A coarse friable sandstone occurs in some localities of the tertiary formation, but it is unfit for durable structures, as is fully shown by the Capitol at Washington, and some other buildings in which it has been used.

CRÉTACEOUS FORMATION.

The cretaceous formation in the eastern part of the United States makes its first appearance in New Jersey, where it was long since recognized, and from this locality were derived many of its most characteristic fossils described by Dr. Morton. It occupies a broad belt in New Jersey and Delaware; and, conforming to the extent and direction of the tertiary beds, it appears at intervals in Virginia and in North and South Carolina, wherever it is exposed by the denudation of the superincumbent tertiary beds. It thence stretches across the northern part of Georgia, central Alabama, and Mississippi, and trends northward along the outcrop of the palæozoic rocks beyond the mouth of the Ohio into the State of Illinois; thence on the west of the Mississippi, following the line of the palæozoic strata through Arkansas, it expands to a great width in Texas. Northward again, it is traced, with varying breadth, along the eastern slopes of the Rocky Mountains and the tributaries of the Missouri, beyond Fort Mandan on that river. On the whole, the cretaceous deposits extend

from north to south more than twenty-four degrees, or from the tropic of cancer to the 48th degree of north latitude.

Economical Products and Agricultural Conditions.—No products have been sent to the Exhibition from this formation.

Green-earth, green-sand, or, as it is usually termed, marl, of the cretaceous series is extensively used in New Jersey and further south by agriculturists. It is sometimes nearly or entirely destitute of fossil shells; while in some localities it has large numbers of them in its composition. The fertilizing effects are mainly due to the contained potash, and perhaps also to sulphate of lime, derived from the double decomposition of sulphate of iron and the carbonate of lime from the fossil shells.

Notwithstanding the immense extent of the cretaceous formation in the United States, no true chalk has been discovered. The calcareous beds thus far known are only useful for burning into lime, and are not used for building or ornamental purposes.

Small deposits of iron, often phosphate of iron and iron pyrites, occur in this formation, but they are not of economical value.

Lignite is found in small quantities, and fossil wood of several species is known. On the Upper Missouri and on the Yellow Stone Rivers the beds of lignite are extensive, and may at some future time be of economical value.

The area occupied by the cretaceous and tertiary formations, between the Mississippi river and the Rocky Mountains, is much greater than the whole area of silurian, devonian, and carboniferous strata between the Alleghanies and the Mississippi; and probably greater than the space occupied by all these rocks together in the limits of the Eastern United States. These formations, therefore, extending so far beyond the limits of the other formations, are destined to have an important influence in the future history of the country. Much of this great area is destitute of forests, and often of shrubs; the surface is barren, and much of it of such a character that it can never be converted to agricultural uses, being often a stiff clay, both in the cretaceous

and tertiary formations. The climate is so dry that in summer the soil is parched and cracks to such a degree as to destroy all vegetation. Small alluvial tracts alone are capable of cultivation, and vast areas of country deserve to be, as they are, designated the *Mauvaises Terres*.

OOLITIC OR LIASSIC FORMATION.—(JURASSIC.)

The formations which have been recognised as belonging to this period occupy a belt of ten or twelve miles wide by a length of fifty miles, west of Richmond (Virginia), and may be denominated the Chesterfield basin. The Deep River basin in North Carolina is a similar formation, extending, with some interruptions, nearly across the entire width of the State. These can only be regarded as separate parts of what has been one continuous formation.* Up to the present time this is the only geological group in the United States which has from its fossil remains been positively recognized as belonging to the age of the oolite or lias.

This formation rests upon a floor of gneissoid and granite rock; and the coarser grits and sand-stones of the series consist of the cemented materials of these ancient rocks. Higher up, the rock has the character of a micaceous schist, which in the upper beds becomes highly argillaceous.

Economic Products: Coals, &c.—A distinguishing feature of the formation, and one of vast economical importance, is the existence of several valuable coal-seams. These are wrought in the vicinity of Richmond, and near the Deep River, in North Carolina. The whole thickness of the formation in Virginia is 800 feet, and the coal-seams are confined to the lower 150 feet. In some places, two or three seams are known to occur, but in the Virginia basin, to the south of James River, these various seams are united into one vast bed of from 20 to 40 feet in thickness.

* The question of the age of the interrupted belt farther west, which is also a continuation of the formation in New Jersey, and the same as that of the Connecticut River valley, is not yet fully determined.

The quantity of coal shipped from this basin, according to the best estimates at which we are able to arrive, is more than 150,000 tons annually. The coal-seams in the same formation in North Carolina have been less explored, and thus far no considerable quantity of coal has found its way to market, for want of means of transportation. Facilities of transport, however, are likely to be soon afforded by the completion of the slackwater navigation of Deep River.

The chief economical products of this formation are coal, mill-stones, building-stone, &c. No specimens from this formation were presented in the Exhibition.

NEW RED SANDSTONE, SHALE, AND CONGLOMERATE.

The conglomerates, sandstones, and shaly deposits so well known in the valley of the Connecticut River through Massachusetts and Connecticut, and along the Hudson River valley, and thence through New Jersey, Pennsylvania, Virginia, and North Carolina, have been usually regarded as belonging to the new red sandstone, or triassic period. In the two States last mentioned, the deposits now under consideration lie in similar insulated troughs or basins to the westward of those already described, and differing from the former more in negative than in positive characters.

This formation has its greatest breadth in New Jersey and Pennsylvania, and gradually diminishes to the south-west,—so that in Maryland and the northern part of Virginia it is but a narrow belt, the continuity of which becomes interrupted in the latter State. These insulated basins lie in the same line as the continuous belt, and are doubtless parts of a once continuous series.

In the Connecticut River valley there is a belt of this formation, having a length of 100 miles, and a width of from ten to twenty miles. It is in this valley that it has been studied with more care than elsewhere, and from whence we have derived more of its characteristic fossils than from any other district. Its organic remains consist of fossil plants of the genus *Voltzia* and others, numerous fossil fishes, also bipedal tracks

which seem for the most part referable to birds, together with those of quadrupedal animals.

Economical Products of the New Red Sandstone Formation.

Building-stones.—The Connecticut sandstone, though occupying a very limited area, furnishes at the present time more architectural and common building-materials than perhaps all other geological formations in the country. The stone is supplied to all the maritime cities of the United States, and even to the interior.

This sandstone is likewise quarried in New Jersey, and at some points on the Hudson River, in the State of New York. The stone used in the construction of Trinity Church, in New York City, is sandstone of this age, from the Passaic River, New Jersey.

Copper and Lead.—The only metals or ores of importance known in this formation are those of copper and lead. In several localities in Connecticut copper ores occur in this rock, though they have been wrought with but partial success. The principal mine in this rock in Connecticut is the Simsbury copper mine, in the town of Granby. The ore is vitreous copper, with small quantities of variegated copper and malachite. The mine has not been worked for several years.

In New Jersey it would appear that this formation affords copper ores in many localities; but, notwithstanding numerous attempts to work them at different times, they have been finally abandoned. The blue and green carbonates are the prevailing ores. The grey and blue sulphuret, with red oxides of copper, have been found in some of the mines; and, more rarely, native copper, and phosphate and silicate of copper. The ores do not occur in regular veins, but appear to be disseminated through certain layers of the slaty part of the formation; sometimes aggregated in considerable quantities, and giving promise of success to the mining operations.

In Pennsylvania, in the counties of Montgomery and Chester, some of the productive veins of lead and copper ores, which lie near the junction of this formation with

the gneiss rocks, penetrate both systems, while other veins lie wholly within one or the other set of strata.* The localities mentioned afford large quantities of lead and copper ores; and some of the mines are producing valuable returns. The veins in the shales and sandstones are observed to be more prolific in copper than in lead; and the same lode, which is lead-producing in the gneiss, becomes copper-bearing in the superior rock; or the lead-ores become greatly reduced, and the copper largely preponderates.

The principal ores are sulphuret and phosphate of lead, and sulphuret and carbonate of copper.† These ores will be again referred to in the description of the older metamorphic rocks.

Exhibition. — Besides the specimens from the Wheatley mine, the products of this formation in the Exhibition were rough specimens and small blocks of dressed sandstone from the quarries at Portland, Connecticut, on the Connecticut River; also sulphate of baryta from Cheshire, Connecticut.

COAL-FORMATION, OR COAL-MEASURES.

The series of sedimentary and other deposits, constituting what is usually designated as the Coal-measures, or great Coal-formation, are, in the United

* Report of Professor H. D. Rogers on the Wheatley, Brookdale, and Charlestown mines.

† The Wheatley mine, which is in one of the lodes penetrating both the gneissic and sandstone formations, has afforded the following minerals, all of which were represented at the Exhibition:—

Sulphate of Lead, crystallized.	Blue Malachite.
Phosphate of Lead.	Black Oxide of Copper.
Arseniate of Lead.	Native Copper.
Molybdate of Lead.	Oxide of Manganese.
Chromomolybdate of Lead.	Native Sulphur.
Arsenio-phosphate of Lead.	Native Silver.
Antimonial Sulphuret of Lead and Silver.	Quartz, crystallized.
Sulphuret of Lead.	Cellular Quartz.
Sulphuret of Zinc.	Oxide of Iron with Silver.
Carbonate of Zinc.	Brown Hæmatite.
Silicate of Zinc.	Brown Spar.
Sulphuret of Copper.	Sulphate of Barytes.
Green Malachite.	Iron-pyrites.

States, extremely similar to those of Europe. The foundation or underlying rock is usually a conglomerate, or coarse sandstone, with quartz-pebbles. In some parts this rock is not present, and shaly beds with coal rest upon the limestone below. The succeeding beds consist of sandstones more or less fine, sometimes of conglomerate, or conglomeratic sandstone, shale, limestone, coal, and fire-clays. The immense thickness of this formation in some localities is truly astonishing, and the changes of condition that must have been required to produce the alternation of beds of different materials, and of such magnitude, is no less a matter of surprise.

The great coal-formation of the United States is one of its principal and most striking geological features, as it is by far the most important of all in its economical influences. The eastern Alleghany or Appalachian coal-field extends from the extreme northern part of Pennsylvania to the central part of Alabama, its length being more than 750 miles, and its greatest breadth more than 180 miles; exclusive of the anthracite basins which lie detached upon the eastern side of the main field. The superficial area of this coal-field has been estimated, by Professor H. D. Rogers, at about 63,000 square miles.

The great western coal-field, or, as it has been usually termed, the Illinois coal-field, occupies the larger part of the State of Illinois, and parts of Indiana and Kentucky. The late surveys of Dr. D. D. Owen have shown that this coal-field has, in its full limits, a much greater extension in Iowa and Missouri than had before been supposed.

It is true that the part west of the Mississippi River is not only separated from the eastern or Illinois portion by the river-channel, but that this river runs along a gentle anticlinal axis, the elevation of which has contributed in part to the separation of these two portions of the great western coal-field.

This western portion, lying in the States of Iowa and Missouri, occupies an area two-thirds as great as that part on the east of the Mississippi. It is the opinion of Mr. Hall, and other geologists of note, that this coal-field extends to the south-west beyond the limit of any

careful geological explorations as yet made, though probably not reaching beyond the parallel of the silurian and metamorphic regions of southern Missouri.

Its greatest extent from the south-east to the north-west, or from the head-waters of Green River, in Kentucky, to its northern limit on the Des Moines River in Iowa, is more than 550 miles; while its greatest breadth across Illinois and Missouri, in an eastern and western direction, is more than 400 miles; and from its northern termination in Iowa, to its present known limits on the Osage River at the south, is more than 300 miles.

This western coal-field, therefore, including the area on both sides of the Mississippi, has a much greater superficial extent than the Appalachian coal-field. Indeed, that portion alone of this western field which lies east of the Mississippi has a superficial area nearly equal to the Appalachian coal-field; while that on the west of that river adds fully half as much more to the entire extent.

Still farther to the south, we know that a coal basin of considerable extent exists in Arkansas. This was perhaps originally a part of the same field as that in Iowa and Northern Missouri, and may have been separated from that by the elevation of the belt of metamorphic rocks; or this belt may have existed in its present elevated form as an island in the ancient ocean in which the sedimentary materials of the coal formation were deposited. Other coal basins, either as small detached areas, or as parts of one great field, are known to exist still farther to the south and west; and from the fact that the great underlying carboniferous limestone has been traced into New Mexico, and at intervals to the Rocky Mountains range, still farther north, we may infer that the coal measures will be found, if not co-extensive with it, to occur at least at intervals and in isolated basins over this vast area.

Besides these, there is a smaller field in Michigan, which has thus far proved unproductive, and which from its position, in a low flat country, is not likely to become available at present. Its geographical position is such as would give it superior advantages, lying as it does upon the navigable waters of Lake Huron, and being

more accessible to the commerce of the great northern lakes than either of the other coal-fields. At the present time we have too little accurate knowledge regarding it to speculate as to its future comparative importance.

There is likewise a small area of the nearly unaltered coal-measures,* in Rhode Island and Massachusetts. The relative position of these beds, together with those of Nova Scotia, when viewed in connection with the age and character of the intervening country, suggests the idea that these detached portions may once have been united with the Alleghany coal-field; and further, that this was originally continuous with the western field; and, in fact, in their original or undisturbed condition, the carboniferous formations may have been nearly co-extensive with the area of that part of the United States lying east of the Rocky Mountains.

In conclusion, besides these immense and inexhaustible coal-fields on the east of the Rocky Mountains, specimens of coal have been brought by Captain Stansbury from beyond Fort Laramie; coal has also been obtained at Bellingham Bay on Puget's Sound, Washington Territory; little is known, however, of the age or geological associations of either. The specimens of the latter are so similar to the ordinary bituminous coals of the coal-measures, that no essential difference is perceptible, and we are thus led to hope that on the western coast of the United States this important source of progress and wealth may be found.

Economical Products.

Coal of the Coal Formation.—The rapid disappearance of the forests from the northern and middle portions of the United States, together with the steady and increasing advancement in manufacturing operations, have necessitated the general use of mineral fuel. Although comparatively but few years have elapsed since

* The partially altered beds of the coal-measures here spoken of are those which are productive in coal; but I am satisfied that a much larger extent of country in New England consists of the coal measures, in a more or less highly metamorphic condition.

the introduction of coal into use as ordinary fuel, the present enormous and steadily increasing consumption renders the consideration of supply, and the means of bringing this supply within the facilities of transportation to towns and cities, a matter of great importance.

The earlier manufacturing operations of the United States began in New England, where the abundance of water-power compensated for the absence of mineral fuel, and supplied the requirements of the manufacturer. At the present time, however, since the American coal-formations are better known, and the supply has kept pace with the wants of the community, it is beginning to be felt that manufacturing operations must depend upon the abundance and unfailing supply of fossil fuel. The ratio of increase in the consumption of anthracite coal in the United States may be understood from the fact, that in 1820, 365 tons were used; while in 1847, the increased demand reached the amount of nearly 3,000,000 tons; and of bituminous coal during the same year, more than 2,000,000 of tons were consumed.*

In 1851, it was estimated that the bituminous coal consumed in Pittsburg, and shipped to southern ports, including that from the Monongahela, amounted to more than 1,000,000 tons.

The anthracite and bituminous coal-fields of Pennsylvania and Maryland, which form outliers in advance of the great coal-field, are reached with facility from the Atlantic coast. The Ohio, Monongahela, Kanawha, and other smaller but navigable streams traverse and penetrate the Alleghany field on the west, while its northern and eastern margins approach within thirty or fifty miles of Lake Erie at Cleveland, and within less than one hundred miles of Buffalo, which is the terminus of the Upper Lake navigation and the commencement of the canal navigation of New York.

On the south, the same coal-field reaches within 200 miles of the Gulf of Mexico, and is there penetrated by streams which admit the transportation of coal from the mines to tide-water; and the coal for the steam-navigation of the Gulf will eventually be supplied in that direction. At the present time, large quantities

* R. C. Taylor's "Statistics of Coal."

of coal are shipped down the Ohio, and thence to New Orleans, making a distance of more than 2000 miles of river navigation.

The western coal-field is traversed by the Ohio, the Wabash, the Illinois, the Mississippi, the Missouri, and the Des Moines; thus the greatest possible facilities are afforded for transportation by natural navigation. The north eastern boundary of the Illinois coal-field reaches to within 80 or 90 miles of the southern extremity of Lake Michigan, and is connected with Chicago both by canal and railroad. Add to all these facilities for transportation the numerous railways, in progress and projected, over a nearly level or slightly undulating country, and it will be obvious that the whole of this great western country can readily be furnished with an abundant and cheap supply of mineral fuel.

The coals of the small districts included in Massachusetts and Rhode Island are anthracites of a low degree of combustibility. This character of the coal, together with the irregular condition of the beds, in the midst of a much disturbed and highly metamorphic region, have caused them to be little sought for; and of the ten or twelve workings commenced at different times, few have been continued.

The anthracite basins of Pennsylvania produce anthracite of a superior quality, and from its accessibility it has furnished a large part of the fuel used in the towns and cities of the Atlantic coast.

A specimen of anthracite coal of enormous size, from the Mammoth vein, Wilkesbarre, Pennsylvania, was presented at the Exhibition by citizens of that town. This mass showed a vertical section of the vein, being a shaft 5 feet square at the base and 30 feet high; weighing about 60 tons. Several other large masses, one 10 feet long by 4 wide, and $3\frac{1}{2}$ high, were exhibited from the same locality; and specimens of the same bed from other localities.

Coals from the Carbondale and Pittstown mine, a collection of about sixty varieties of anthracite from Schuylkill county, and several other specimens of coal, were presented at the Exhibition.

Bituminous coals from Maryland were exhibited in

large masses, showing the thickness of beds, 11 and 15 feet respectively. Numerous specimens of bituminous coal accompanied samples of iron-ore from several places in Pennsylvania.

A collection representing the bituminous coals of Perry, Hacking, Vinton, Jackson, and Mahoning counties, Ohio, also specimens from Kentucky and Virginia, were exhibited.

Iron-Ores.—The coal-fields of the United States contain rich deposits of the iron-ores which usually occur in the coal-measures. These are chiefly the carbonate and peroxide of iron; the latter mainly resulting from partial decomposition or change of the former, which is argillaceous, calcareous, or siliceous in its composition. In Pennsylvania and in Ohio, where these ores are wrought to a greater extent than elsewhere, the beds appear to be inexhaustible, and will supply for an indefinite period the requirements of advancing physical improvement and civilization.

In Tennessee, Alabama, and Western Virginia, the coal-formation abounds in iron-ores. In the western coal-field less is known of this connection of coal and iron, the extent to which iron is manufactured being far less than in the east. The geological survey of Illinois, now in progress, has already shown that this State is richly supplied with iron-ore in the midst of her inexhaustible coal-fields; although there are as yet but two furnaces in the State. In Missouri, iron from these ores is manufactured to some extent, yet too little is known to warrant a conclusion as to their abundance.

The iron-ores from the coal-formation presented at the Exhibition were chiefly from Pennsylvania; and from that State was furnished a very full collection, not only of the ores from the coal, but from other formations.* The collection comprised the ore and furnace-products, viz., ore, coal, slag, pig-iron, as well as manufactured iron;—ores from geological formations below the coal, and occurring in the midst of the coal-fields, being here exhibited in company with the coals by which they are smelted.

* Further mention of these will be made under the headings of "Iron Ores."

Iron-ores from the coal-formation were exhibited from Vinton, Jackson, and Hocking counties, Ohio; and also from one locality of the coal-formation of Missouri. A good series of specimens presumed to be from the same formation were exhibited from Alabama.

In estimating the relative abundance and accessibility of this metal in the coal-formation, it will be recollected that only a small part of what is known in these immense coal-fields was represented in the Exhibition; and that what is known is comparatively but a small portion of what exists in the entire area; and when we reflect that the ores belonging to this formation, with their accompanying mineral fuel, are distributed more or less abundantly over an area of more than 160,000 square miles, we may have some faint conception of its vast amount, and of the important results of its influence on the future industrial interests of a country like the United States.

The States of Tennessee and Alabama are known to be rich in iron-ores of the coal-formation; as also Virginia and Kentucky; though specimens were exhibited from only one of these States.

Limestones.—In nearly every part of the coal-fields there occur beds of limestone of marine origin, alternating with shales, sandstones, and beds of coal. In some places the coal and limestone are in actual contact; and some of the ores occur in connection with the limestones. These beds of limestone furnish the necessary flux for the reduction of ores of iron, and also lime for ordinary building-purposes.

Sandstones.—The beds of sandstone, alternating with the shales and coal-seams, often furnish an excellent and durable building-material. Some of the more friable sandstones, which are free from iron, are used for glass-making.

Fire-Clays.—Some of the coal-seams are underlaid with beds of fire-clay, of greater or less thickness; and in some parts of the formation there are extensive beds of fire-clay not directly associated with coal-seams. This material is used for fire-bricks, stoneware or pottery, water-pipes, and drain-pipes, and is everywhere co-extensive with the great coal-fields.

CARBONIFEROUS LIMESTONE FORMATION.

The great limestone formation immediately underlying the coal-measures, and which in the carboniferous districts is usually a conspicuous feature in the topography of the surrounding country, is an unimportant and inconspicuous rock upon the margin of the greater part of the Alleghany coal-field. On the eastern margin through Pennsylvania, it can scarcely be said to exist; unless the thin bands of limestone associated with the red shale of No. XI. (Pennsylvania Geological Reports) may be regarded as this rock.

In Virginia this limestone becomes greatly expanded; and, in the southern part of the State, it acquires an important thickness. In Tennessee, following the same direction, the limestone forms a narrow belt along the eastern side of the coal-field, and continues to its southern extremity in Alabama. In Northern Alabama, upon the west and north-west sides of the coal-field, this limestone area is greatly expanded, and continues into Tennessee; forming a very conspicuous feature in the topography of the Cumberland Mountains. In the northward, however, the limestone gradually diminishes, and is finally lost before reaching the Ohio River, or becomes so merged in the adjacent sandstones as to pass unobserved.

When we turn to the western or Mississippi coal-field, we find the extent and importance of this formation greatly increased. Along the eastern side of this coal-field the limestone occupies a broad belt, extending through Indiana and Kentucky, and re-appearing on the western side of this part of the basin, or along the valley of the Mississippi, where it is deeply excavated for many miles by the channel of that river, and often forms high cliffs along its banks. It occupies a belt of country of varying width, on one or both sides of the Mississippi, from a short distance above the Ohio to the mouth of Rock River, more than 300 miles in extent, and passes both east and west under the coal-measures on either side. It appears at numerous intervals along the Missouri, and, as far as known, it forms a broad belt encircling the whole of the western division of the coal-

field. Farther west it appears near Fort Laramie, and is the principal stratified rock in the vicinity of the Great Salt Lake. Its occurrence in Texas and New Mexico is also known, though its limits have not been defined. In Michigan, little is known of this formation, though limestone, referred to this period, occurs in several localities along the western side of the coal-field. The great variety of character exhibited by this limestone in the west, together with other considerations, has induced Dr. D. D. Owen to separate it into a lower and upper formation. The whole is 390 feet thick,* and is divisible into twelve different beds, characterised by lithological differences.

Thus, over an extensive region in the west, this group of limestone beds, with their layers of marl, or soft argillaceous sandstone, and marly partings with earthy beds of limestone, imparts a character of fertility to the country surrounding the western coal-field, unknown in the same geological associations elsewhere in the United States. On the northern, eastern, and western margins of the Alleghany or eastern coal-field, there is a broad belt of country in which no important calcareous formation exists; and here the limestone products can only be obtained from many miles beyond the outcrop of the coal-measures, or from the thin calcareous beds which alternate with the coal-seams. The effect of this geological difference is perceptible, not only in the architectural character of the buildings, but in the agricultural condition of the country; in the one case, the belt around the coal-measures producing a grazing country; while in the other, the corresponding belt, holding similar relations to the coal-measures, and in the same latitude, possesses a highly calcareous soil and gives origin to a grain-growing region of the first order.

But not only does the belt of country surrounding the coal-fields present this contrast of character, the regions within the areas of the coal-fields are not less strikingly different. This surrounding calcareous formation, together with the many alternating beds of lime-

* This thickness is much less than that estimated for the limestone in the same association in Virginia and Tennessee.

stone in the coal-measures themselves, all of which are frequently cut through by the river-channels and deep valleys, have served to distribute calcareous matter very generally and abundantly throughout the region. From this cause, perhaps, together with the accumulation of soils derived from the calcareous beds of lower formations in the northern districts, the area within the coal-fields of the west, in their wide extent of prairie and level lands, present a very different aspect from those parts of the country within the eastern coal-field, although the coal-fields hold similar geological relations.

Economical Products of the Carboniferous Limestone.

Lead.—The carboniferous limestone, throughout the greater part of its extent, preserves its normal characters, and is generally unproductive of mineral substances. In the southern part of Illinois, where the strata are much disturbed, it is traversed by several veins which have been worked for lead.* The lodes contain galena, blende, fluor-spar in large quantities, calc-spar, &c.

Lead-ores likewise occur in the carboniferous limestone of Tennessee and Alabama, but not in quantities sufficient to be wrought. A vein of lead-ore in proximity to the coal-measures is worked in Arkansas; but this may perhaps be found to be in the carboniferous limestone.

Building Stones.—This limestone affords an excellent and cheap material for building, easily quarried and dressed. Some of the beds are extremely fine-grained and compact in texture, admitting a good polish, as do also some portions of the lower beds of the limestone, which are oolitic in structure.

Several blocks, and some smaller polished specimens of this limestone from the vicinity of St. Louis, were shown in the Exhibition.

† The State Geologist of Illinois, Dr. J. S. Norwood, expresses much confidence in the prospective value of these veins.

RED SHALE OF THE CARBONIFEROUS LIMESTONE
FORMATION.

In connection with this limestone it would seem necessary to notice a very important formation of red shale, which, in the absence of the limestone, lies directly beneath the conglomerate of the coal-measures. This shale formation (No. XI of the Pennsylvania survey) has a thickness of 2,949 feet at Pottsville, and extends in a broad belt along the eastern margin of the coal-fields throughout Pennsylvania and Virginia.

Economical Products: Iron.—It is economically important from being the repository of iron-ores which are wrought in many places in Pennsylvania, not only along the borders of the coal-measures, but at numerous points within the basin, where the superincumbent strata are cut through. The ores of the red shale are chiefly carbonates of iron, with variable proportions of silica, alumina, &c. They yield from 60 to 80 per cent. of carbonate of iron, and some of them yield peroxide of iron in about the same proportion. Specimens of these ores were shown in the Exhibition.

DEVONIAN FORMATION.

The group of limestones, shales, and sandstones, forming this division of the palæozoic rocks which in the United States are generally recognised as constituting the Devonian system, are a heterogeneous assemblage. In the descending order, this series begins with the formation No. X of the Pennsylvania Survey; which, though it may be a debateable ground between carboniferous and devonian, will be for the present included in the latter. To this we have to add the shales and sandstones of the Catskill Mountains, and the Chemung and Portage Groups, together with the shales and calcareous beds of the Hamilton Group of New York, and their extension westward, known as the Black Shale, and Waverly sandstone, or fine-grained sandstones of Ohio, Indiana, Iowa, &c. The whole of this series of deposits rests upon a limestone included in

the same formation, and which is at least co-extensive with them.

We shall first notice the extent and general character of the sedimentary strata of the upper portion, and afterwards describe the limestone formation.

First group.—The series of strata under consideration has a far greater thickness in the eastern part of the United States, as New York and Pennsylvania, than in the western part. In the former it is clearly a littoral deposit, and the coarser materials are accumulated in this part of the formation; while towards the west, the finer materials only have been transported, and consequently the accumulation is less. For this reason also, its economical resources, and its influence upon the topography of the country and the fertility of the soil, vary to a great degree in different parts of the formation.

In those situations where we find the greatest development of these groups, the lower beds have been composed of a fine impalpable mud, succeeded by others formed of a similar fine mud, with a large admixture of calcareous matter; and sometimes the rock becomes arenaceous, with calcareous matter in smaller proportion. Succeeding this, are often some thin calcareous bands, which, however, are not constant. To these again succeed soft shales, or shaly sandstones, which are followed by arenaceous beds, and a successive alternation of these with bands of shale, of greater or less thickness. To these succeed red and green shales and sandstones, the structure being in some cases coarser than that of the lower deposits, but often shaly, or consisting of alternating arenaceous and shaly beds. This is the formation composing the Catskill Mountains. To this must be added the formation No. X, which is a coarse sandstone or conglomerate, and sometimes a shaly mass, with an admixture of conglomerate.

This formation may be considered as occupying nearly all the southern half of the State of New York, from the Hudson River, extending along the northern outcrop of the Pennsylvania coal-basin, and forming the southern shore of Lake Erie from near Brussels, N. Y., to Cleveland, Ohio. From this point it curves round in a broad belt, skirting the coal-measures along the

entire western margin, but gradually thinning out to the southward. On the east it follows the outline of the Alleghany coal-field from Pennsylvania to Alabama.

In like manner, the black slate and fine-grained sandstones encircle the Michigan coal-field, and form a broad belt, of several hundred feet in thickness, along the entire margin of the Illinois coal-field, cropping out beneath the well-marked carboniferous limestone, into which they sometimes appear to graduate, or they alternate with the lower beds of the latter rock. Along the Mississippi valley these sedimentary rocks crop out at numerous points beneath the carboniferous limestone; and the fine sandstones, so extensive in the west of this great coal-field, are probably of the same age.

Second group.—At the base of all these sedimentary deposits lies an immense limestone formation, important less from its thickness, than from the area which it occupies, and the positive evidence which we have of its once having been a continuous and uninterrupted coral-reef, over an area of not less than 500,000 square miles.

Within the limits of the United States, it is first recognized in its unaltered condition in New York, New Jersey, and Pennsylvania, and extending thence westward. Its most conspicuous outline, however, is from the Helderberg Mountains, on the Hudson River, near Albany, westward throughout the entire extent of New York. Crossing the Niagara River at Black Rock, extending through Upper Canada in a line nearly parallel to the coast of Lake Erie, and crossing into the northern part of Michigan, it forms the western boundary of Lake Huron in its northern part, quite to the Straits of Mackinac, and appears in an enormous outlier, capping Mackinac Island and Gross Cap. Its position to the south-west of these points is in the bed of Lake Michigan, having been denuded, with the softer beds beneath it, and excavated to form the bed of this lake.

The anticlinal axis extending from the western part of Lake Erie, by Cincinnati, to the southern part of Tennessee, brings up this limestone, which occupies a broad belt on either side of the lower strata that have been here elevated. In the central part of Ohio, it extends from Sandusky, south, to the Ohio river, and

thence into Kentucky. It has an equal extent in Eastern and South-eastern Indiana, reaching the Ohio River at the Falls at Louisville, and passing thence through Kentucky, where it occupies a considerable area, it extends into Tennessee, skirting the irregular outline of the silurian formation of that State.

In a north-west direction from where we leave this rock in Northern Indiana, it follows a course parallel to the northern outline of the Illinois coal-field; and extending by the head of Lake Michigan across the Mississippi River, it constitutes in part the formations of the valley of the Red Cedar River in Iowa.

Notwithstanding the remarkable persistence of this group, it has nowhere a very great thickness; and indeed it is for the most part a very thin deposit, reaching, perhaps, at its maximum, no more than 350 feet, and it is usually less than 100 feet. In its north-western extension in Iowa, Dr. Owen estimates it at no more than 60 or 70 feet, and its furthest south-western limit is scarcely more than half this thickness.

Third group.—At the present time geologists are inclined to extend the limits of the Devonian system, in America, still lower than the limestone just described, and to include within the signification of this term a series of grits and sandstones which intervene between the last-named limestone and another limestone formation below. In New York two distinct members are recognised, the Cauda-galli grit, and the Oriskany sandstone. The former is a close, compact, and fine-grained mass, of a dark colour, and nearly destitute of fossil remains; while the lower member is a coarse, porous, or loosely aggregated sandstone, containing an abundance of fossils.

These grits and sandstones have their northern termination in the Helderberg Mountain, near the Hudson River; and in their extreme western prolongation they do not reach beyond 200 miles, and present several interruptions within this distance. The entire thickness in the State of New York does not reach 200 feet. The lower member of the group is much more persistent than the upper, and extends southward through Pennsylvania, and into Virginia, and in this direction

acquires in Pennsylvania, according to Professor H. D. Rogers, a thickness of 700 feet.

Economical Products of the Devonian Rocks.

Iron-ore, Building Materials, &c.—A system so varied in its composition, and occupying so great an extent of country, must necessarily present a variety of useful products. The principal materials of economic value are iron-ores, limestone for lime, hydraulic limestone, building-stones, sandstone for building and for fire-stones, flagging-stones, &c.

At the junction of the Chemung and Cattskill Groups, Nos. VIII and IX of the Pennsylvania Survey, there occur bands of fossiliferous iron-ore, not unlike one to be mentioned in the Upper Silurian formation, or Clinton Group of New York. These ores yield from 30 to 50 per cent. of peroxide of iron. Iron-ores also occur associated with the limestone at the base of No. VIII of the Pennsylvania Survey.

These ores are described as of good quality and abundant in quantity, in the State of Pennsylvania, and they occur still further to the south. In the western extension of the limestone described, no ores of importance are known to occur, though the line of junction with the rock next below it is often marked with an ochreous deposit.

The only products of this formation shown in the Exhibition were a few specimens of iron-ore and limestone from Pennsylvania.

UPPER SILURIAN FORMATION.

The formations which in the United States may be included in the upper division of the Silurian system consist of limestones known in New York as the Lower Helderberg Limestone Group, which includes the following members in the descending order: Encrinal limestone, Delthyris shale limestone, Pentamerus limestone, and Water-lime. To these again succeed the Onondaga Salt Group of New York and the great limestone of Niagara, altogether constituting No. VI of the Pennsyl-

vania survey. Below these occur a series of shales, sandstones, conglomerates, and beds of limestone, constituting the Clinton Group of New York; and the whole is terminated below by the Medina sandstone. The two latter-named formations constitute No. V of the Pennsylvania Survey.

These different members or groups of the series have a very different geographical distribution, and require to be separately noticed.

Group A.—The lower Helderberg limestones have their greatest development in the Helderberg Mountains, near the Hudson River, and in New Jersey, Pennsylvania, and Virginia. In Pennsylvania the thickness of the group is estimated at 900 feet, which is four times greater than in New York. In a south-west direction, parallel to the Appalachian chain, this group appears to be co-extensive with the other members of the palæozoic formations. Pursuing it in a westerly direction, however, we find that it thins out; and, with the exception of the lower members, it is not known beyond 100 miles west from the Hudson River. The lower member, or Water-lime, extends to the western boundary of the State.

Group B.—The second division, or Onondaga Salt Group, has a wider range, and may be traced throughout the entire length from east to west of the State of New York, and thence through Canada West, where it is often deeply covered by superficial accumulations. Its course north-westerly is in the direction of Lake Huron, where it has been entirely removed, and the basin of the lake now occupies its place. It re-appears forming the base of Mackinac Island and Gross Cap of Lake Michigan.

From these points its course is again in the direction of the basin of Lake Michigan,* from which, together with the superior limestone, it has been removed.

In Northern Ohio, west of Sandusky city, and along the Sandusky River, it has some importance; but in the southern part of that State, and in the south-eastern

* For the origin and relative position of the valleys of Lakes Huron and Michigan, see a Paper by James Hall, in Foster and Whitney's Report on the Lake Superior Land District.

part of Indiana, although easily discoverable in numerous localities, its thickness is unimportant.

The most persistent member of this part of the silurian system, is the Niagara group, consisting of shale and limestone, or of limestone alone, and well known as forming the barrier at the Falls of Niagara. Although this group is often extremely thin, and with difficulty recognised, along the eastern outcrop of the palæozoic series, it becomes very important in the western part of the State of New York. In the eastern part of the State it is a thin bed of little note, but augments in thickness towards the west, producing a conspicuous feature in the topography of the country, in the great terrace, or mountain ridge, as it is termed, which extends from Rochester, by Lewiston, New York, Queenstown and St. David's, Canada West, to the head of Lake Ontario. Thence westward, this formation produces the prominent headland, Cabot's Head, between Lake Huron and Georgian Bay; and, in its continuation, it forms, in great part, the Manitoulin Islands. From these west by the Straits of Mackinac, it forms the northern shore of Lake Michigan and the peninsula between that lake and Green Bay; and continuing thence, it forms the western shore of Lake Michigan nearly to its southern extremity. Farther west, it occupies the elevated portions of the country in Southern Wisconsin and Northern Illinois, and, extending into Iowa, spreads out into a wide area between the Mississippi and the Red Cedar River.

The anticlinal axis before mentioned, which extends from Nashville to Lake Erie, brings up this limestone in the islands near the west end of that lake; and, extending thence south-westerly, it is broken through by the Lower Silurian about fifty miles north of Cincinnati, and thence extends on either side of this axis into the States of Kentucky and Tennessee, constituting the lower beds of limestone at the Falls of the Ohio, and holding the same position in the well-known fossiliferous localities of Perry county, Tennessee.

Group C.—We may for the present include in one the two succeeding formations, the Clinton group and the Medina sandstone of the New York Survey;—a series of

beds consisting of shale, shaly sandstone, conglomerate, beds of limestone, iron-ore, and a massive formation of soft red sandstone at the base. This group, either entire, or represented in some of its members, is nearly co-extensive with the preceding. It follows the same course, cropping out from beneath it, and often aids in giving prominence to the bold outline of the superior limestone. This group is well developed in all its members, in the central part of New York, its most northerly limit in the United States, if we except some parts of Maine, where, however, its extent is little known, and the Green Mountains, in which it may be represented by some metamorphic rocks. From its point of greatest development in Oneida county, this formation becomes more calcareous and of less volume to the westward; and at the Niagara River, the whole formation consists of a bed of shale and a bed of limestone. North-westerly through Canada, though greatly reduced in thickness, it follows the line of the superior limestones, and is seen in the islands of Lake Huron. It is distinctly recognised on the eastern shore of Green Bay, and again in Wisconsin, which, as far as now known, is the most westerly limit of the rocks of this formation. Some of the limestone beds of this group, as defined in New York, are to the westward intimately blended with the Niagara limestone. The same is true of these rocks along the great central axis, though here the sedimentary beds of the group are scarcely to be recognised.

From the south-west end of the Shawangunk Mountain in New York, this group extends through New Jersey, and into Pennsylvania, where it attains the great thickness of 2,000 feet. It is persistent in some of its members through Virginia and Tennessee, and reaches the southern termination of the palæozoic rocks in Alabama.

The base of the upper division of the Silurian system is marked by an immense accumulation of thick-bedded sandstone, both of coarse and fine texture, and massive strata of conglomerate, with thin beds of shale or shaly sandstone. The conglomerate often contains pebbles of large size, and frequently the materials composing

these beds are but partially worn, the fragments preserving to a great degree their angular form.

Notwithstanding the coarseness of the materials of which this rock is often composed, they are so cemented as to suggest the idea that some portions of the siliceous matter may have been in partial solution at the time of the aggregation of the mass. The less rounded character of the materials, and the compact nature of the rock, together with the peculiarities of its bedding, and other features, serve to distinguish it from the conglomerates of the coal-measures.

This rock is first recognised in the valley of the Mohawk, south of Utica, where it altogether constitutes a mass of less than 20 feet in thickness, and is soon lost both towards the east and the west by thinning out, while towards the south it passes beneath the overlying formations. Seventy miles to the southward, however, it abruptly appears in great force in the Shawangunk Mountain, which commences a few miles from the Hudson River, near Kingston, and thence it ranges through the counties of Ulster, Sullivan, and Arago, to the Delaware River. The formation extends thence southwesterly, through New Jersey, Pennsylvania, Maryland, and Virginia, constituting a prominent feature in the topography of the country throughout its entire extent. Including the Shawangunk Mountain in New York, and its continuation, the Kittatinny Mountain in Pennsylvania, it forms an almost continuous mountain-range from the Hudson River in New York to the northern part of Virginia. We should not omit to observe, that although the Shawangunk Mountain terminates abruptly on the north-east a few miles from the Hudson, yet the conglomerates and coarse sandstones are infolded with the underlying slates of a preceding period, in the contorted and metamorphic rocks of Eastern New York.

This formation usually imparts a conspicuous character to the scenery and topography of the country which it traverses, and of itself it constitutes the mountain range described. The surface is usually barren, and often quite destitute of vegetation over considerable areas; and the white sandstone, often conspicuous in

large naked patches, gives a peculiar aspect to some parts of the mountains.

And it is worthy of remark, that these rocks present the very significant feature of an ancient coast-line formed during a period of disturbance, and marking in the most decisive manner the period of greatest change in the fauna which occurred during the deposition of the entire series of the palæozoic rocks.

Economical Products of the Upper Silurian Rocks.

Iron-Ore.—The substance of greatest economical importance in this part of the system is iron-ore. The strata known in New York as the “Clinton Group” contain one, and sometimes two distinct beds of iron-ore, alternating with beds of limestone and shale. This iron-ore appears to be nearly co-extensive with the formation. In the western part, however, where the formation has become interrupted and thin, iron-ore is known to exist in only a single locality in Wisconsin. The ore is fossiliferous, as are the adjoining bands of limestone, and often highly calcareous in its composition. It is much prized and extensively used in the manufacture of iron in Pennsylvania and New York.

Small quantities of iron-ore occur in the superior limestones (No. VI of Pennsylvania Survey) in Pennsylvania, but throughout the large part of the area occupied by these limestones, no ore of importance is known.

Lead, Zinc, and Copper.—Galena, blende, and copper-pyrites occur in the Shawangunk conglomerate. At the present time a lead-mine is wrought in this rock, in the Shawangunk Mountain in Ulster county; the products of the mine are galena, copper-pyrites, and a small quantity of blende. This mine has afforded some remarkably large masses of galena, one of which weighed 16,000 pounds.

Further to the southwest, within the State of New York, a vein or bed of sulphuret of zinc in the same formation has been somewhat extensively wrought.

Building-Stone and Millstones.—Limestone everywhere abounds in this part of the system, and some of the finest and most durable structures in the country

are made from limestone of the Niagara group; this is evidenced in the great works along the line of the Erie Canal; and the facility with which this rock is quarried, and the proximity of navigation, have caused its extensive use; it may be recognised even in the city of Chicago, at a distance of 1,500 miles, by way of the lakes, from its source in Western New York.

The Medina sandstone and Clinton groups afford an abundance of fine flagging-stones, as well as, in some parts, excellent building-stones.

Millstones of good quality have long been manufactured from the compact conglomerate of the Shawangunk grit; this rock, in earlier treatises on American geology, was supposed to be identical with the millstone-grit of England.

Salt.—The Onondaga Salt-group, in the State of New York, yields brines of great strength, from which large quantities of salt are manufactured, affording an extensive business as well as a large revenue to the State. The salt manufactured at these *salines* in 1797, amounted to 25,474 bushels; since that time the quantity has been steadily increasing; in 1852 it amounted to 4,922,533 bushels, and in the present year the quantity will extend beyond 5,000,000 of bushels.

Although this formation yields brines for a distance of 200 miles or more along its northern outcrop, yet those which are of sufficient strength to be used in the manufacture of salt are confined within a small area in the neighbourhood of Syracuse, New York.

It should be observed, that the wells from which these brines are obtained are bored in drift or alluvium, and in only a few cases reach to the rock *in situ*. The brine occurs in the drift, having percolated from the superior beds of the group which rise above the level of this valley on the south; and its quantity or quality is not improved by penetrating the strata which lie below the gravel.

Exhibition.—The products of the Upper Silurian in the Exhibition, were specimens of iron-ore from Pennsylvania, and gypsum from New York.

LOWER SILURIAN FORMATION.

The geological formations which at the present time are included in the lower division of the Silurian consist, in the descending order, of a series of argillaceous sandstones, shales, and slates, which are known as Formation III of the Pennsylvania Survey, or the Hudson River Group, including the Utica slate, of the New York Geological Reports. To these succeed limestones of Formation II of the Pennsylvania Survey, or the Trenton, Black River, Birds-eye, and Chazy limestones of the New York Report. To these succeed, as the base of the system, the Formation I, or Calciferos and Potsdam sandstones. These three divisions of the Lower Silurian period require a few words of description separately, though in geographical extent they are, with some modifications, nearly co-extensive.

Group A.—The first-mentioned, or highest division, has a great development towards the north-east; and, entering the United States from Canada, we find it continued along the eastern shore of Lake Champlain, mostly in a partially metamorphic condition. Below Whitehall it expands, occupying a belt on the west as well as on the east side of the Hudson valley, and gradually assuming its normal character. It extends through the Hudson valley as far as Newburg, and thence following a south-westerly direction, we find it continued through New Jersey, Pennsylvania, Maryland, and Virginia, sometimes occupying a single belt of country, sometimes two or three belts, and again uniting into one. In its south-western extension it follows the general trend of the Alleghany range, and corresponds in outline to the preceding and following formations. Westward and north-westward from the Hudson River, these strata pass beneath the lower limestones of the Helderberg from Kingston on the Hudson to the Mohawk; and along this valley they continue westward with numerous undulations, finally rising to the summits of the hills on either side, as the lower rocks are elevated from beneath. Finally they spread out in a broad area upon the eastern shore of Lake Ontario. In Canada they reappear upon the

northern shore of the lake, and are traced uninterruptedly to the head of Georgian Bay, Lake Huron. The basin of this bay, and its continuation in the space between the Manitoulin Islands and the main shore, are caused in part by the excavation and removal of the Hudson River Group, the higher beds of which appear on the northern margins of some of these islands. To the westward, this Group reaches the northern shore of Lake Michigan, forming Pointe aux Baies, between the Little and Big Bay de Noquet. Its place is occupied by the waters of Green Bay, near the head of which, on the eastern side, the higher portions of the group are seen passing beneath the superior limestones. It is seen along the eastern shore of Winnebago Lake, and beyond this it is lost apparently from gradually thinning out. From the Georgian Bay, westward, the character of this formation is argillo-calcareous; the higher beds consist of impure limestone, and arenaceous beds are almost entirely wanting.

This formation has a great development in the region fifty miles around Cincinnati, Ohio, and south-westerly along the axis extending through Kentucky and Tennessee. In this part of the United States it consists of alternating beds of soft shale and thin layers of limestone, with occasional traces of the shaly sandstones which are so constant and characteristic a feature of this formation in its eastern extension.

On the Mississippi River, and in numerous places in Wisconsin and Iowa, there occur some thin-bedded argillaceous limestones with seams of shale, overlying the lead-bearing rock, and holding apparently the position of the Hudson River Group. Admitting this as proved, we are able to trace this group from the north-eastern boundary of the United States, in a south-west direction to Alabama; and from the eastern line of New York, through Canada, beyond the Mississippi river; and we have good reason to suppose, from its appearance in the region of Cincinnati and Nashville, that it underlies the superior formations throughout the intervening area.

Group B.—The second division of the Lower Silurian formation, or the limestone group, consists, in its eastern

extension, of four distinct members: the Trenton limestone, the Black River limestone, the Bird's-eye limestone, and the Chazy limestone. Of these the Trenton limestone is the most persistent and often gives name to the entire group.

This series of limestones is recognized as entering the United States from the north by the St. Lawrence and Champlain valleys, and is known along the St. Lawrence quite to its mouth. We find it continuing with slight interruptions through New York, New Jersey, Pennsylvania, Virginia, and Alabama. Westward from the central part of the State of New York it extends along the valley of the Mohawk by Trenton Falls and Black River to the eastern extremity of Lake Ontario. Thence, crossing the St. Lawrence, it passes through Canada, and appears on the shores of the Georgian Bay, and along the north side of Lake Huron; it forms the greater part of the Island of St. Joseph; and, extending westward between Lake Superior and Lake Michigan, it forms the western shore of Green Bay. Thence it enters the State of Wisconsin, continuing in a course nearly parallel to the western outline of Lake Michigan to within fifty miles of the southern boundary of the State, when it bends westward and occupies a broad belt in the southern part of Wisconsin and Northern Illinois. It extends into Iowa, and, following the course of the Mississippi River, occurs, at intervals, as high as the Falls of St. Anthony. In the axis of elevation which extends from below Nashville to Lake Erie, these lower limestones are seen along the Stones River in Tennessee, and at Frankfort, Kentucky; but they do not appear north of the Ohio river.

The limestones of the Lower Silurian period are co-extensive with the superior shales over the eastern part of the United States; while in the western part, or in the Mississippi valley, they extend beyond the positively known limits of the shales.

This group of limestones, whether recognized in the several sub-divisions, or only as a single mass, is everywhere important. In all the more eastern and southeastern localities, the group consists of limestone, with

occasionally interposed layers of chert and thin slaty seams. Westward the portion of shaly matter increases, and in some places, as at the Falls of St. Anthony, it prevails to such an extent as to render a large proportion of the rock nearly unfit for all economical purposes.

There is a general diminution in thickness, and change in character of the limestones of this group as we progress westward; and in this direction commences the intercalation of another member, which is of little magnitude before reaching Wisconsin, but there becomes developed into a mass of much importance, being the lead-bearing rock (Galena limestone) of Wisconsin, Illinois, and Iowa, and formerly described in the Surveys of this region as a part of the Cliff limestone.

Group C.—The lowest division of rocks included in the Lower Silurian consists of the Calciferous and Potsdam sandstones. The former known as the Lower Magnesian limestone in the States bordering the Upper Mississippi. These two rocks often alternate with each other at the line of junction, and in numerous localities we find a friable arenaceous deposit succeeding the calciferous sandstone, being obviously due to a repetition of the same operations which produced the lower arenaceous beds.

The lower division is for the greater part nearly devoid of calcareous matter; nevertheless, in its western extension it contains partially calcareous bands. The upper or calciferous sandstone was originally so named from its combining the arenaceous and calcareous composition which everywhere marks it in varying degrees. This formation enters the United States from the St. Lawrence valley on the north-east, and stretches across the northern part of New York as far as the outlet of Lake Ontario. It may be followed down the valley of Lake Champlain, and thence with interruptions through New Jersey, Pennsylvania, Maryland, Virginia, and Tennessee. Westward through Canada, it skirts the northern shores of Lake Huron, and becomes more extensively developed on Lake Superior; from the outlet of this lake westward, it spreads out to a

great width in Northern Wisconsin, and extends along the shores of the Mississippi River, forming the high cliffs which are so conspicuous a feature in the scenery between Prairie du Chien and the Falls of St. Anthony.

Economical Products of the Lower Silurian Rocks.

Iron-ore.—The large quantity of iron-ore described by Professor H. D. Rogers, in his “Geological Report of Pennsylvania,” as connected with the limestones of this period, does not, we conceive, compose any part of the formation itself; but the association of the ore with various clays and other deposits clearly indicate for it the same origin as for those other deposits of hæmatite ores which have been described in this report among the products of the tertiary formation.

Lead-ores.—The most important economical product of the Lower Silurian formation is galena, or sulphuret of lead. The lead-bearing rock, or “galena limestone”* of Wisconsin, Northern Illinois, Iowa, and part of Missouri, is a Lower Silurian limestone which has yielded immense quantities of lead-ore for many years past.†

* So named by Professor Hall, who first recognised it as a Lower Silurian limestone (see Geological Report of Lake Superior Land District), it having been described originally as a part of the cliff limestone of the Ohio Reports, or the upper magnesian limestone of Dr. D. Owen.

† The mode of occurrence of this lead-ore is somewhat remarkable, and may be noticed in this place. The metalliferous limestone is from 50 to 80 feet thick, and is a thick-bedded, porous, and friable limestone. This rock is traversed by fissures having a generally north-east and south-west direction, with others crossing these nearly at right angles. The galena occurs in the fissures, those having the most nearly north and south directions containing the largest quantity, or being the best lodes. The ore occurs with calcareous spar, and mixed with or surrounded by clay in the fissures, rarely, if ever, attached to the wall-rock or penetrating it. The limestone below the proper lead-bearing rock is a thin-bedded mass, some of the layers being slaty, and the whole with continuous open fissures. In following the lead-bearing fissures downward, they are found not to penetrate the rock below; and the lode of ore either thins out abruptly or spreads horizontally between the laminae or strata of the subjacent rock. It is quite impossible that the ore could have come from any source beneath the lead-bearing beds; and the only explanation that can be offered is, that they were filled from above by sulphuret of lead

The lead-ores of Missouri occur in the same rock as those of northern Illinois, Wisconsin, and Iowa, and under similar conditions. Veins of galena and blende are known in several localities of the Trenton limestone in the northern part of New York, but these have never been wrought with profit.

Copper Ores—Veins or lodes of sulphuret and carbonate of copper occur in several localities within the limits of the lead-region and in the same association, particularly at Mineral Point, Wisconsin, where these ores were formerly wrought, but ultimately proved unprofitable; they occur likewise in Missouri. They are confined to a rock of moderate thickness, and are productive in their linear extent rather than in depth. Copper ore has also been found in a lower position in the lower magnesian limestone of Wisconsin, but only in a single locality of small extent. On the south shore of Lake Superior, the lower or Potsdam sandstone is associated with extensive beds of conglomerate and an unbroken range of trap rocks which are copper-bearing. The sandstone and conglomerate contain some ores of copper, but the metallic copper occurs mainly in the trap rocks; none of the veins in sandstone or conglomerate are worked at this time.

Marble, Limestone, and Building-stones.—Some of the beds of limestone afford a black marble of excellent

from solution, which, on coming to the subjacent rock with close joints, has spread out horizontally as far as it could penetrate between the laminae, in some instances replacing the fossils of the rock. The only objection that can be offered to this hypothesis is, that whenever the lead-bearing rock is traced beneath superincumbent beds, these are of thin-bedded argillaceous sandstone, with shaly partings, and nearly free from joints. This rock is designated the "Cap Rock" by the miners, and the lead-ore is said always to terminate abruptly against the lower side of the "Cap Rock." The mines which have been worked are mainly in the exposed surface of the lead-bearing rock, and have never been carried very far beneath where it is covered with the "Cap Rock;" and therefore the character and condition of the lodes in the lead-bearing rock beneath the overlying formation are not so well known. If the mines in this position should continue to yield as abundantly, there are still large areas of lead-bearing rocks which remain untouched; but, on the contrary, should they prove less prolific beneath the super-incumbent rock, then we may regard the lead region of the West as destined to be soon exhausted.—*From Manuscript Notes of Prof. James Hall.*

quality, which is extensively used, with marble of other colours, for flooring in halls and public buildings, and also for other purposes. For structures requiring heavy blocks, the lower limestones afford an abundant supply of excellent quality throughout their northern and eastern range, but are of far less value in this respect in their western extension.

The Potsdam sandstone furnishes excellent and durable building-stone and fire-stone.

The slates of the Hudson River group afford roofing-slates in numerous localities in Vermont, New York, and Pennsylvania, and probably farther south. These usually occur on the margin of the metamorphic belt; and, when either entirely unaltered, or too much changed by metamorphic action, they are unfit for this purpose.

Grindstones and Flagstones.—Grindstones of good quality are made from the sandstones of the Hudson River group. Flagging-stones are also abundant in many parts along the eastern exposures, and as far west as Lake Ontario. The thin-bedded Potsdam sandstone in many localities affords good flagging-stones.

Exhibition.—The products of the lower silurian rocks in the Exhibition were encrinal marble from Lake Champlain, and also roofing-slates from the semi-metamorphic slates of this formation, which may with equal propriety be referred to the formation next to be described.

UPPER METAMORPHIC ROCKS.

To draw the line between lower fossiliferous and upper metamorphic rocks is extremely difficult, inasmuch as the formations between the Hudson River and the Atlantic consist of the various palæozoic rocks already described, sometimes in a transitional state, and sometimes perfectly crystalline and devoid of organic remains. All these rocks, however, in whatever degree they may have undergone metamorphic action, may be classed as upper metamorphic rocks, and distinguished from an older series of crystalline rocks to which they are unconformable in stratification, as may be seen at Little Falls, New York, along the valleys of Lake

Champlain and the St. Lawrence, and in numerous other localities. The upper metamorphic rocks comprise the quartz-rocks, or altered sandstones, the finely granular, often micaceous, white and coloured limestones, the schistose rocks, varying from soft and fissile black, green, and reddish slaty rocks, to the micaceous and talcose schists into which they graduate, and various gneissoid, syenitic, and hornblendic rocks—all of which can be recognized as clearly derived from stratified fossiliferous rocks of palæozoic age.*

These formations have been proved to occupy large portions of the New England States, and it is only in small areas, if at all, that the older metamorphic rocks exist within their limits. The extension of the same formation south-west, in a direction parallel to the older fossiliferous rocks, shows a wide area occupied by the rocks of this age, co-extensive indeed with the palæozoic formations from north to south.

The direction and dip of strata composing these formations are usually well preserved, though sometimes, within limited areas, they are obscured, and numerous dislocations and inverted axial folds render their study difficult.

The larger portion of this formation consists of rocks older than the coal-period; while to these we find super-added, in the eastern part of New England, the metamorphic carboniferous rocks. In numerous localities, these metamorphic rocks can be traced as positive continuations of the fossiliferous strata, the fossils gradually disappearing as the beds assume a more crystalline condition, from the gradually increased metamorphism; all doubt of the cause of the obliteration of organic remains being thus removed.

The rocks of this age produce very marked physical features in the topography of the countries which they occupy. Entering the United States on the north by the St. Lawrence valley, we find the rocks of palæozoic age, which thus far have been observed in their undisturbed and unaltered condition, assuming slight

* Granite, which is usually referred to true igneous origin, occupies comparatively little of the area described.

lithological changes, which increase until the strata become more or less crystalline; the fossils are gradually obliterated; the beds become elevated, often vertical, and even appear in overturned axial folds; and, rising into numerous hills and ridges, they finally assume the character of mountain ranges, as in the Green Mountains of Vermont and the White Mountains of New Hampshire.

Devonian metamorphic.—The altered rocks of the age of the Chemung and Portage groups of New York, forming part of the Devonian, are recognized by Messrs. Logan and Hunt as appearing in great force at Gaspé, and are known to be highly developed in the State of Maine. These rocks, in their metamorphic condition, skirt the eastern part of New England, forming a part of the White Mountains; and, passing beneath the anthracite coal-formation of Massachusetts and Rhode Island, constitute with the latter the greater part of the metamorphic and crystalline formations on the east of the Connecticut River.

Silurian metamorphic.—In that portion of the country lying between the Hudson River on the west and the Connecticut River on the east, the more or less metamorphosed rocks consist of those formations already described as silurian. In the western part of this belt the quartz-rocks or hard sandstones, the crystalline limestones, and various slaty rocks terminate above by coarse gneissic and hornblendic beds, which are recognized as the altered forms of the Potsdam sandstone, the Trenton limestone group, and the Hudson River group, with occasional and interrupted beds of the Shawangunk conglomerate, infolded with the slates, and forming the summits of the most conspicuous ridges.

The upper silurian rocks have been traced by Messrs. Logan and Hunt from their unaltered condition in the St. Lawrence valley to within the boundary of the State of Vermont, where they assume the condition of micaceous limestones, interstratified with micaceous slates.

The lower part of this metamorphic formation, or chiefly that composed of the lower silurian slates and

associated arenaceous beds, constitutes the true auriferous belt, as has been abundantly proved in the northern extension of these rocks, and we are well warranted, from numerous observations in the Southern States, in inferring that the auriferous belt of Virginia, North and South Carolina and Georgia is of the same age. Whether the auriferous rocks of California are of the same age as those of the upper metamorphic rocks of the Eastern United States, is a question which cannot now be decided.

Economical Products of the Upper Metamorphic Rocks.

Gold.—The most prominent and important product of the metamorphic rocks of this age is gold, which occurs more or less abundantly throughout the whole extent of the formation from Canada to Georgia. The gold is obtained either directly from the rocks themselves, or from the auriferous debris derived from their destruction by natural causes. At the present time the gravel and sand, resulting from the disintegration of these rocks, are searched for gold on the Chaudière River in Canada; and gold has been found in the rocks and in the gravel in several places in Vermont and Massachusetts; though they have never proved productive of any considerable amount. From the facts here adduced, it appears to be demonstrated that the gold is not indiscriminately distributed through all the rocks of this age, but is in reality confined to a comparatively narrow belt.

Iron Ores.—The iron ores directly connected with these rocks are not often productive; though, from the decomposition of iron pyrites and other causes, beds of iron-ore of secondary origin frequently occur. Some iron-ores of this formation occur in workable quantities in Vermont and New Hampshire; and one or more beds of little economical value are known farther to the south in Massachusetts.

Chromic Iron Ores and Serpentine.—Associated with the rocks of this age occurs chromate of iron in numerous localities, from the northern limits of the United States, as far south as Virginia, and probably still

farther. These ores have been wrought in Maryland and Pennsylvania.

In connection with these ores occur chlorite beds and serpentine rocks, the one apparently co-extensive with the other. The part of the formation bearing these products, however, is not continuous, but occurs at intervals where certain beds existed in the original sedimentary deposits. The serpentines, or *Verd antique*, are of beautiful varieties; and among their localities may be mentioned Millford, near New Haven, Connecticut, and Cavendish and other towns in Vermont.

Copper Ores.—Sulphurets and carbonates of copper frequently occur in the gold region of Virginia and North Carolina, and in the same formation in Maryland. The copper ores of Bristol, Connecticut, and some other localities in that State, must also be referred to rocks of this period.

Tin Ore.—The tin ore (oxide of tin) described by Dr. Jackson as found in the town of Jackson, New Hampshire, occurs in rocks of this age. Tin-ore in small quantities often accompanies the gold in Virginia and North Carolina.

Lead Ores.—Galena, carbonate, sulphate, and phosphate of lead are known in rocks of this age, but their economical value has never been fully tested. Sulphuret of lead occurs in considerable quantities in some of the copper mines recently opened in Maryland.

Silver.—Native silver occurs in Davidson county and other localities in North Carolina.

Building Stones.—Whether we regard the syenitic rocks of New England as belonging to this period, or as igneous and intrusive rock, they are nevertheless so intimately connected with these upper metamorphic rocks, that it is necessary to speak of them under the same head. The firm and durable syenite of the neighbourhood of Boston, known as Quincy granite, so much prized as a building-material, and so extensively used, belongs to this formation. Still further eastward, in the State of Maine, building-materials of this kind are wrought to considerable extent. This syenite is usually of lighter colour than that of Quincy, but becomes darker by the action of the weather.

Flagging Stones.—In nearly every part of this formation flagging-stones and step-stones of good quality are obtained.

Millstones.—The syenite in some localities is sufficiently quartzose to produce good millstones, which are manufactured in the neighbourhood of Salem in Massachusetts, and other places.

Whetstones.—The talcose and mica-slates of this age are often sufficiently siliceous to be used as whetstones or hones.

Statuary Marble.—White and variegated marble of various qualities are found in these formations. They result mainly from the metamorphism of several beds of lower silurian limestone, which vary in character in their normal condition. In the State of Vermont some beds of statuary marble of excellent quality have been found.

Fine marble occurs in numerous localities between the northern line of Vermont and the city of New York, and large quantities are obtained from Vermont, Massachusetts, Connecticut, New York, and Pennsylvania.

The marble from these localities is extensively used for building and decoration, &c., the coarser varieties for floor-tiles and ordinary building purposes.

Mica.—This mineral, which occurs in the metamorphic rocks, or associated with belts of crystalline intrusive rocks, is a substance of economical value. Large quantities are annually used for the doors and sides of stoves, which are so extensively manufactured in the United States.

The entire supply at the present time is obtained from two localities in New Hampshire, Grafton and Acworth.

Exhibition.—The products of this formation presented in the Exhibition are specimens of gold from the rocks in place in Maine, Vermont (a crystallized specimen in quartz), Virginia, North and South Carolina, and Georgia, and some from California. The principal exhibited specimens of gold were from the gravels derived from these rocks, and which have been already enumerated under the head of Drift or Alluvium.

Silver was exhibited from North Carolina; copper ores from Connecticut, Maryland, and North Carolina; lead ore from Massachusetts, Maryland, and Virginia; tin ore from New Hampshire; chrome and iron ores from Pennsylvania and Maryland; plumbago from New Hampshire; varieties of marbles from Vermont, Connecticut, New York; mica from New Hampshire.

OLDER OR LOWER METAMORPHIC ROCKS.

In many parts of the United States there are broad areas occupied by crystalline rocks, which in age and lithological characters are quite distinct from the preceding. For these it is proposed to adopt the term *Older or Lower Metamorphic*, to distinguish them from those which are clearly altered rocks of the Palæozoic period. They are known to be of prior date, and in many cases, if not always, to have acquired their crystalline structure and metamorphic condition previously to the deposition of the surrounding sedimentary formations of the age of the oldest Palæozoic rocks. In numerous localities the Potsdam sandstone, which is the oldest known fossiliferous rock in the United States, lies in a horizontal, or nearly horizontal position against the inclined masses, or rests upon the vertical edges of the rocks of this age; proving the latter to be of long anterior date.

The formation consists in a great degree of syenite, gneiss, and various hornblendic, micaceous, and talcose schists, &c., with highly crystalline limestone: the whole still preserving evidence of stratification to a degree which warrants the opinion that they were originally sedimentary rocks which have been metamorphosed by igneous agencies. Among the evidences of the causes of this change, we find large intrusive masses of granite and other rocks generally regarded as of igneous origin, penetrating the stratified crystalline rocks, of which the system is in a great measure composed. The whole system is likewise penetrated by numerous dykes of trap, which are sometimes of great width and extent. The prevailing and characteristic rock of this formation is

a syenitic gneiss, generally of firm and compact texture. The divisional planes are often obscure, and are frequently lost in the granitic or syenitic structure. One of the most constant and characteristic accompaniments of this formation is magnetic iron-ore.

The chain of mountains on the north of the St. Lawrence, and extending parallel with that river as far as the Thousand Islands, is mainly composed of this formation. We find the same rocks extending through Canada to the shores of Lake Superior, occurring on both sides of this lake, and stretching westerly to the sources of the Mississippi.

Some portions of the mountain-ranges of Maine and New Hampshire may, perhaps, belong to this formation ; but the extent and limits of such portions have not been defined, nor have these beds been distinguished from surrounding rocks of more recent origin.*

In Northern New York this formation rises into mountains of 5000 feet in height, but generally its elevation is much less. In this region it occupies an area of a somewhat triangular shape, having a length of nearly 150 miles from north to south, and about 125 miles from east to west, or from Lake Champlain westward to the St. Lawrence river. The more elevated ridges are towards the centre of this tract. To the north and south it gradually dies out, not however without producing some disturbance among the superincumbent silurian rocks. In the southern part of New York this formation reappears, rising into elevated ridges and mountains, which, however, scarcely attain one-half the elevation of those in the northern part of the State. From the southern limit of New York it enters New Jersey, forming an almost continuous range of mountainous country from the New York boundary to the Delaware River. From the Delaware River to

* In Canada Mr. Logan recognised another series of metamorphic rocks, resting upon those just described, and of anterior date to the newer metamorphic ; thus making three divisions. This middle formation is made up of sandstones, conglomerates with red jaspery pebbles, beds of slate, and limestone. "The slates are greenish, and highly chloritic, and often containing epidote ; sometimes they assume the character of conglomerates, from the presence of pebbles of syenite."

the Maryland State boundary, the older metamorphic rocks extend through the south-eastern part of Pennsylvania in two narrow belts, one of which is continuous, and the other occurs only in insulated patches in the midst of formations of more recent date.

The rocks of this age continue in the same general direction through Maryland, Virginia, and North Carolina, and are known as the Blue Ridge or South Mountains, the highest parts of which in Virginia reach the elevation of 4000 feet. Continuing south-westerly, this formation probably extends more or less interruptedly to the southern limits of the metamorphic formations in Alabama.

The rocks of this formation have been shown to occupy a broad belt on the southern shore of Lake Superior,* occupying, with some slight interruptions, the coast of the lake from the neighbourhood of Camp River to Point Abbaye; they extend westerly with gradually expanding width into Northern Wisconsin; and in the central part of that State reach as far southward as the parallel of the outlet of Winnebago Lake. Thence the course of the formation is to the north-west, reaching the Mississippi River north of the Falls of St. Anthony.

There is an isolated belt of this formation in Missouri, one in Arkansas, and another in Texas.

Economical Products of the Older Metamorphic Rocks.

Iron-Ores.—In point of economical resources this formation, both in Canada and the United States, is perhaps second only to the coal-formation. The magnetic iron-ores from Canada, forming immense veins or masses, so fully illustrated in the London Exhibition of 1851, were from the rocks of this older metamorphic period. This mineral, either as magnetic protoxide of iron, or mingled with anhydrous peroxide in various proportions, is characteristic of the formation everywhere. In Northern New York the mountains are

* Report of Foster and Whitney on the Lake Superior Land District, 1851; and of D. D. Owen on the Chippeway Land District, 1852.

traversed by veins or beds of the same ore, which have the appearance of intercalated beds running parallel to the schists, and having a width or thickness of from 2 or 3 feet to more than 100 feet, and can often be traced for a mile or more in length.* Numerous beds are opened in the vicinity of Lake Champlain, where the ore is largely used in manufacturing iron, and whence also it is shipped southward to the valley of the Hudson, where it is used for smelting with inferior ores, to improve the quality of the iron.

The ores of the Adirondack region, in Northern New York, have been successfully used in the manufacture of very fine iron and steel, which were likewise shown in the London Exhibition in 1851.† In the western part of the metamorphic region here described, the iron-ores are chiefly the peroxide or specular iron-ore. In the southern part of the same State, extensive beds of magnetic oxide of iron occur in the same rocks, and are wrought to considerable extent. In New Jersey, Pennsylvania, and Maryland, these magnetic ores are wrought; but farther south they seem to have attracted little attention.

On the southern shore of Lake Superior the rocks of this class contain extensive beds or veins of mixed magnetic ore and peroxide of iron.‡ In the western extension of the same formation, and in the vicinity of Montreal and Bad River, in Wisconsin, beds of magnetic iron-ore are known to exist.§ The iron-ores, a mixture of magnetic iron and peroxide, of the Iron Mountain and Pilot Knob in Missouri are derived from rocks of the same age. Similar ores occur in the metamorphic region of Arkansas.

Copper-Ores.—The rocks of this age in Northern New York have yielded small quantities of copper-ores in several places, but no mines have been profitably

* The details of many of these have been given in the Geological Reports of New York, and others have subsequently been discovered.

† Jury Reports, pp. 17 and 18.

‡ Foster and Whitney's Report on the Lake Superior Land District. Part 2. 1851.

§ Dr. D. D. Owen's Report on Wisconsin, Iowa, and Minnesota.

wrought. The Bruce Mine on Lake Huron, and others on the northern shore of Lake Superior, which yield copper, chiefly from the sulphurets, are in this formation, or in the intermediate metamorphic division recognized in Canada by Mr. Logan.

Lead Ores.—The lead ores of Rassie and its vicinity, in Northern New York, occur in rocks of this age. The lead and copper mines of Montgomery and Chester counties, Pennsylvania, already mentioned in connection with the new red sandstone, occur in the gneiss rocks of this system. These veins promise to yield largely of these two metals. The line of demarcation between these rocks and the newer metamorphic is not so clearly defined in the region southward as to enable us to designate with certainty the mines which may be in this or in the preceding formation. In this direction both series appear to be more prolific in ores, excepting iron, than the same formations in New England and New York.

Zinc Ores.—Zinc-blende often occurs with the lead-ores in this formation; and veins of blende, sometimes with a small admixture of galena, are found. Thus far this ore has proved of no economical value. The red oxide of zinc and franklinite of New Jersey must be regarded as of this period. The intimate connection of these products with the older gneiss rocks, and their associated minerals, point to this age; though the crystalline limestone found in the same geological association is regarded by Professor Rogers as of silurian age. The red oxide is largely used in the manufacture of the white oxide of zinc, and the mixture of this ore with the franklinite, ground in oil in its natural state, forms a brown paint which is much used. Although producing metallic zinc of excellent quality, it is not manufactured at the present time. The franklinite of the same mine has, it is said, of late been successfully used in a process by which the oxide of zinc is obtained and the iron reduced, both processes being accomplished by the same furnace operation.

Phosphate of Lime—In fine crystals, and in a massive form, occurs in rocks of this age. In one locality in

Northern New York,* a vein or bed of this mineral was discovered, which at one time promised to prove of great value for agricultural purposes. It has, likewise, been found in considerable quantities in New Jersey.

Porcelain Earth.—Granite proper forms but a small part of the extent of country occupied by the metamorphic rocks of the United States. It occurs in both the formations as intrusive bands, dykes, or more extended masses. Many of these granite rocks are very coarsely crystalline, and consist mainly of feldspar, with small proportions of mica and quartz. The feldspar, whether in a partially decomposed condition or in its natural state, is largely used in the manufacture of porcelain and the finer kinds of earthenware.

Marble and Building-stones.—The lower metamorphic rocks usually afford an abundance of rather coarsely crystalline limestone, with occasional beds of finer quality. None of it, apparently, can come under the designation of statuary marble; it is, however, adapted to many purposes for which the coarser varieties of white or clouded marbles are used; and in many localities it is a good building-material. In Northern New York it is sometimes mixed with serpentine, which gives it a variegated appearance. On the southern shore of Lake Superior these marbles are described as of a beautiful pink colour, traversed by veins of red; others are blue and dove-coloured, and beautifully veined. The gneiss and granite from this formation afford excellent building-materials of a great variety and colour; and in many places these may be quarried in massive blocks. The situations where the best examples occur are not easily accessible for the means of transportation to the larger cities.

Fire-stones, Hones, &c.—The talcose slates of this period often furnish good fire-stones, which, when the divisional planes of the rock are not of too frequent occurrence, and when blocks of sufficient dimensions can be obtained, may be used for the construction of

* See also Mr. Logan's notice of phosphate of lime in the metamorphic rocks of Johnstown, East Canada. Geol. Journ., vol. viii., p. 210.

iron-furnaces. Sometimes beds of a fine material, as potstone or compact steatite, are found associated with the limestone.

Some of the slates contain sufficient silica to adapt them for hones or whetstones. This material, of good quality, has been found on the south shore of Lake Superior.

Plumbago and Crystalline Minerals.—Plumbago occurs in considerable quantities in rocks of this age in Northern New York.

In some localities the rocks of this period are extremely rich in beautiful minerals. Amongst these may be mentioned, fine crystals of apatite, zircon, spinelle, sphene, augite, tourmaline, &c.

Labrador feldspar, in large crystalline masses, is not of unfrequent occurrence in Northern New York. This mineral, when polished, is very beautiful; and some of the finer specimens have been set in gold and worn as ornaments.

Exhibition.—The products of the older metamorphic rocks presented in the Exhibition were iron-ores from Northern New York, New Jersey, Pennsylvania, and Maryland; some large masses from Lake Superior and Missouri, with manufactured iron from most of the localities, and fine specimens of steel from Adirondack mines; also,—copper-ores, from Pennsylvania; lead-ores, from Northern New York and from Pennsylvania; red oxide of zinc and franklinite, with products of manufacture, from New Jersey; hone-slate, from Lake Superior.

Besides these, numerous beautiful crystalline minerals from the older metamorphic formations of Northern New York and New Jersey were exhibited.

THE TRAPPEAN FORMATIONS.

New Red Trap Rocks.—The most conspicuous formation of this kind in the Eastern United States is that which is associated with the new red sandstone, the extent of which has already been described. Accompanying the sandstone of the Connecticut River valley, trappean or basaltic rocks occur in such force as to present marked features in the topography of the country. Mount Holy-

oke and Mount Tom, in Massachusetts, are conspicuous examples of this kind. The East and West Rock, near New Haven, are also prominent points in the landscape—which are due to this trappean formation. Less conspicuously the trap occurs in numerous, often parallel, ridge and dykes, and in long continuous belts throughout the extent of the river valley, for 100 miles above its mouth: The Palisades of the Hudson River, and numerous prominences of trap in New Jersey, are all of the same age, and have the same geological associations. Finally, this trap-formation may be traced through Pennsylvania, Maryland, Virginia, and North Carolina, everywhere accompanying the sandstone rocks.

One of the constant accompaniments of this trap-formation is native copper; but, throughout its entire extent, it has never been found in available quantities. Other ores of copper often occur in the sandstones adjacent to the trap-rocks; and there appears to have been some connexion between the intrusion of these trap-dykes and the segregation of the copper ores. The trap-rocks of the period of this new red sandstone are often columnar in character, and their mode of weathering is by vertical joints. This feature is less prominent in the trappean rocks next to be described.

Lake Superior Trap-rocks.—The second great trap-formation is that of Lake Superior, which occurs in connexion with the sandstone of the Lower Silurian period. This formation is most conspicuously developed upon Keweenaw Point, and extends thence in a broad belt west and south-west, conforming generally to the shore of the lake. It is flanked on the northern side by conglomerates, and on the southern by sandstones; and a narrow belt of trap runs through the conglomerate parallel with the main central formation. Towards the western extremity of Lake Superior, this trap-formation becomes interrupted, and occurs only in insulated dykes or ridges piercing the sandstone. Isle Royale presents many features in common with Keweenaw Point; the range of the trap is similar and parallel, though there is but a small development of the conglomerate. On the north shore of the lake, within the territory of the United States, the trap extends in numerous narrow

belts or dykes entirely to the western shore of the lake. Thence, at several points between this and the Mississippi River, above the Falls of St. Anthony, belts of trap are of frequent occurrence.

Beyond this river less is known of its extent or character; but, from the little information we have, it appears probable that the same formation occurs at intervals between the Mississippi and the Rocky Mountains.

Throughout the whole, the associations are so similar as to leave no doubt that this trap is all of the same age. On the St. Croix River it is thrust through the lingula-beds of the Potsdam sandstone in great bosses or knobs; and in Northern Wisconsin it occurs in nearly similar situations, more or less connected with the lower sandstone, but frequently associated with syenite or syenitic gneiss.

The trap-formation of Lake Superior, where it appears in its greatest development, is the repository of immense quantities of native copper, which in that region everywhere characterizes the presence of trap of a certain variety. In a map of Keweenaw Point, recently published by Mr. Whitney, United States Geologist, we find the trap of Keweenaw Point thus described. Amygdaloidal trap, bearing native copper; porphyritic trap, bearing sulphuret of copper; and crystalline trap, in which the veins are not productive. The principal part of the formation of Keweenaw Point is composed of the former kind of rock; a narrow strip passing longitudinally through the centre, represents the crystalline portions; and a broad belt on the south side, adjoining the sandstone, is of the latter variety.

Trap-rocks of the Western Regions.—From the borders of Texas to the country of the Blackfoot Indians, and still further north, trappean and basaltic rocks are found at frequent intervals. Westward, in the great plain between the Rocky Mountains and the Sierra Nevada, rocks of this character are of frequent occurrence, though we do not know their geological relations. Again, to the north-west, in the Rocky Mountains and along the Columbia as far as the Pacific coast, there are numerous and extensive basaltic and volcanic rocks.

But it would require too much detail for a Report like the present, to give a connected view of all the observations that have been made upon these igneous rocks in the great area here indicated.

Trap-rocks of the Metamorphic Series.—A system of the trappean rocks of a different age, consisting of trap, greenstone, porphyry, &c., traverse the metamorphic rocks of the periods above described. These, however, rarely produce any distinct features in the topography of the country, nor do they appear to have had any connection with the upheaval of the mountain ranges in which they occur. They traverse these rocks in various directions, apparently filling fissures or joints, of which several are sometimes parallel to each other. Although these dykes occur everywhere in the United States, they are more numerous and extensive on the northern shore of Lake Huron and Lake Superior.

In the eastern part of New England, and particularly near the coast, the strata are traversed by these dykes; and more extended belts of similar rocks occupy portions of the metamorphic area. The porphyritic belts appear sometimes to have resulted from extreme metamorphism, or igneous fluidity, of previously existing formations.

Economical Products of the Trappean Formations.

Copper.—Native copper in large quantities is obtained from the trap-rocks of the Lake Superior region, where numerous mines are opened on the south shore of the lake. The copper occurs in sheets of greater or less thickness, in veins cutting the trap-range nearly at right angles, and associated with various vein-stones. These sheets of copper are of variable extent, weighing from a few pounds to 80 tons. The produce of copper from the mines of Lake Superior, during the year 1853, will reach 4000 or 5000 tons.

A mass of native copper in the Exhibition from one of these mines weighs 6,300 pounds; it is cut upon four sides, and the thickness between the two natural surfaces is more than two feet: this was cut from a mass weighing 40 tons.

The sulphurets of copper in the porphyritic trap, on the south shore of Lake Superior, have not yet been wrought to any great extent.

Silver.—The native copper contains a small amount of native silver, and this metal also occurs in small nodules or irregular masses in the copper, or attached to its exterior surface, and also in the accompanying trap.

In these cases the quantity of silver is usually small, but some masses of large size have been discovered in the *debris*, associated with lumps of native copper. More recently, a vein of silver has been wrought upon the north shore of Lake Superior. Specimens from this place were exhibited in the Exhibition.

Building-stone.—The trap-rocks, which are traversed by numerous joints, separate into irregular angular blocks used for rough walls, and to some extent for buildings. The rapid breaking down of these rocks along the Palisades of the Hudson River, by the action of water and frost, renders them accessible; and large quantities are annually transported to the city of New York and its vicinity.

GENERAL REMARKS.

From the foregoing sketch of the economic geology of so large a portion of North America, it will be seen that the great metalliferous belts of the United States are the two nearly parallel and contiguous ranges of metamorphic rocks, which extend almost uninterruptedly from the north-eastern extremity of the United States to Alabama. To these two principal zones must be added an area of considerable breadth in Northern New York, one of similar character on the south shore of Lake Superior, a small area in Missouri, one in Arkansas, and another in Texas. On the western side of the continent we have the metalliferous belt of the Pacific coast, extending through California and Oregon. Too little is known of the Rocky Mountains to enable us to speak with any degree of confidence with regard to their future mineral produce.

Permanent and productive mines of the metals will not be found beyond the areas which have been thus hastily sketched out. The general depositories of mineral wealth, therefore, are within moderate proximity to the coasts. The copper and iron region of Lake Superior lies upon navigable waters, communicating by artificial channels with the Atlantic. The coal formation, the source and foundation of every enterprise, stretches almost the whole length of the country, from the great lakes on the north to the Gulf of Mexico on the south.

The natural distribution, therefore, of these sources of wealth and power, combined with the physical features of the entire country, leave nothing to be desired, with respect to the materials and incentives for its physical progress and development.

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CLASS X.—TOPOGRAPHICAL AND HYDROGRAPHICAL
SURVEYS; CHARTS AND MAPS.

Introduction.—Massachusetts is, I believe, the only State which has undertaken a trigonometrical survey of its territory; and this was independent of, or subsequent to, her geographical survey. It is certainly somewhat surprising that a people, who are straining every energy for physical advancement, should yet neglect a subject of so much economical importance.

In some of the older States such a survey is more essential than in the newer ones, and in the former there exist the means of accomplishing the object. When this is effected, and maps have been constructed combining topography and geology, these must become the foundation of every new enterprise in internal improvements, which would be planned and carried forward in accordance with the knowledge there expressed.

Under Class X we have to notice the maps and charts which exhibit progress in their several departments, or which present new facts of economical or scientific interest. The only works of this kind which particularly claim our attention, are the maps of the United States Coast Survey, under the charge of Professor A. D. Bache, and the Wind and Current Charts of Lieutenant Maury.

Coast Survey.—The coast survey of the United States, under the able direction of Professor Bache, may be regarded as by far the most important scientific work now in progress in the United States. Both in its scientific results, and in its economical and utilitarian influences, its importance cannot be over-estimated; and from these considerations we may be permitted to introduce a short sketch of its history and progress, with a general summary of the objects proposed to be accomplished, and a notice of the mode of procedure, with the results thus far obtained.*

* I take this opportunity of returning my thanks to the officers of the Hydrographical Survey at Washington, for the courteous and valuable assistance which they gave me in drawing up this part of the Report.

History of the Establishment of the Coast Survey.—

The importance of an accurate survey of the coast was felt by the people and authorities of the United States at an early period of their history as an independent nation; and a plan for the execution of a complete geodetic and hydrographical survey was adopted by President Jefferson, who appointed the late Mr. F. R. Hassler to the office of Superintendent.

Mr. Hassler went to Europe in 1811 to procure the necessary instruments, all of which had to be constructed; but, owing to the disturbed condition of Europe and the subsequent war of the United States with England, he was unable to obtain them, or to undertake the prosecution of the work, until the year 1817, when a commencement was made on the Bay of New York. Shortly afterwards, however, the work was suspended by the failure of Congress to appropriate funds for its prosecution; and it was not until 1832 that it was revived, Mr. Hassler being again appointed Superintendent.

At the time of Mr. Hassler's death, which occurred in 1843, the survey had been extended from the base near New York, eastward to Rhode Island, and southward to the capes of the Delaware and the upper part of Chesapeake Bay.

Professor Alexander Dallas Bache was appointed Mr. Hassler's successor; and under his direction the survey has been expanded in all its branches, and vigorously prosecuted up to the present time.

System pursued by the present Superintendent.— According to the plan developed by Professor Bache, the operations are carried on simultaneously on different parts of the coast, which, for the purposes of the survey, is divided into eleven sections, in each of which the survey is executed independently on its own base line and geographical determinations. When completed the whole will form a continuous survey of the coast, presenting an unbroken chain of triangulation; with several base lines verifying each other, and numerous determinations of latitude, longitude, and azimuth, fixing geographical positions, and contributing largely to our knowledge of the figure of the earth.

Plan of the Survey.—The general plan of the survey may be briefly stated as follows:—

After a reconnaissance to determine the best plan of work, a base line is measured, and a primary triangulation, having sides as long as the limits of vision or the nature of the country will allow, is carried on along the coast.

Astronomical observations to determine the latitude and direction of the meridian are made at a number of the stations, and the longitude of some cardinal point in each section is determined. Magnetic observations are also made, furnishing the variation of the compass for the charts, and incidentally the elements of the earth's magnetism.

On the sides of this primary triangulation is based the secondary triangulation, determining prominent points a few miles apart along the coast and bays, furnishing points of departure and checks for the topographical survey, which is next executed. The hydrographical survey lastly furnishes soundings and observations on tides and currents, and completes the material required for the charts, which are drawn, engraved, and printed in the office of the Coast Survey.

Constitution of the Bureau of the Survey.—The *personnel* of the survey consists of civilians and military and naval officers; the first class forming a permanent nucleus, and being composed of persons of scientific and practical ability, a great part of whom have been trained to the work under the present Superintendent; while the officers of the army and navy are put upon the survey or withdrawn from it, according as their professional duties may permit. The geodetic and topographical work is performed by the civilians and army officers, while the hydrographical survey is made by officers of the navy, all acting under the immediate orders of the superintendent, and reporting their results to him. A unity of plan is thus secured highly conducive to accuracy and despatch, and which has not been attained on similar works in other countries, where the geodetic and hydrographic surveys are carried on separately; in consequence of which the latter fails to

derive from the former those data which are essential to its perfection.

Progress and method of the work of the Survey.—After this brief summary, a more detailed notice of some of the methods used in the work and its results will not be uninteresting.

Measurement of Base-lines.—Up to the year 1853, six principal base-lines had been measured, two of which are now connected by a primary triangulation. These, as well as a third, were measured with the apparatus designed by Mr. Hassler, and fully described by him in the “Transactions of the American Philosophical Society,” Vol. IV, the measurement being made with iron bars and by optical contact. The subsequent bases have been measured with an apparatus designed by Professor Bache, and constructed under his direction in the office of the Coast Survey. In this apparatus the measuring bars are arranged upon the compensating system, first used by Colonel Colby in Great Britain, and by Mr. Borden in the survey of the State of Massachusetts, but the mode of obtaining the compensation differs entirely. A principle is also introduced, which, though obvious enough, had not been applied before. A bar of brass and a bar of iron, of the same dimensions, exposed to the same source of heat, will not become heated equally in equal times, the difference depending on the different conducting powers of the two metals, their different specific heats, and the different powers of their surfaces to absorb heat. The bars then, if of equal sections, will not be compensating when the temperature is changing, however perfectly the compensation may be effected at any stationary temperature. The sections of the bars must, therefore, be so proportioned to their conducting power and specific heat, as to cause both to have the same temperature during variable temperatures of the atmosphere, their surfaces being easily made to absorb equally by giving them the same coating.

The lever of contact and level, first used in the adjustment of standard measures by Bessel, has been adapted to this apparatus; the contact between two

sets of bars being made by a blunt knife-edge and a plane of agate. The rapidity and accuracy with which the measurement of a base-line can be made with this apparatus can leave but little to be desired. From remeasurements made of portions of the base-line on Dauphine Island, it appeared that the probable error in measuring a mile is about two-hundreths of an inch.

The Fire Island base, on the south side of Long Island, and the Kent Island base in Chesapeake Bay are connected by a primary triangulation. The former is 8·7 miles, the latter 5·4 miles long, the shortest distance between them is 208 miles; the distance through the triangulation is 320 miles: the length of the Kent Island base, as computed from the Fire Island base, through a series of 32 triangles, differs but 4 inches from the measured length.

The principal base-lines measured are in the States of Massachusetts, New York, Maryland, North Carolina, South Carolina, and Alabama. In other sections of the survey preliminary base-lines have been measured by means of wooden or iron bars and some simple apparatus: all of these will be superseded by measurements with the apparatus described.

Apparatus for measurement of the Angles.—The instruments used for measuring the angles of the primary triangulation are a 30-inch and a 24-inch theodolite, by Troughton and Simms, both fitted with reacting micrometer microscopes, and a number of 12 and 10-inch repeating theodolites, by Gambey. The latter instruments are great favourites on account of their admirable graduation, and the principle of repetition causes them to be preferred in cases where the instrument has to be elevated on wooden structures, the perfect stability of which cannot be depended on. The Atlantic coast of the United States south of New York, and the shores of the Gulf of Mexico, being without any considerable eminences, and in general densely wooded, artificial elevations are resorted to in order to carry on a triangulation having sides of from 10 to 16 miles in length. Wooden structures, varying from 25 to 40 feet in height, have been erected on various plans by the assistants of Professor Bache, and have proved amply

steady for measurements of angles with the repeating instruments.

The large (30-inch) theodolite was designed by Mr. Hassler, and is used by Professor Bache in the execution of the triangulation in the north-eastern part of the United States. Mr. Hassler followed the usual rule of observing at such times only when the conditions of vision appeared to be entirely unobjectionable. This rule is attended with serious loss of time. Mr. Bache has increased the rapidity of the work, and improved rather than diminished its accuracy, by making observations under conditions ordinarily favourable and of frequent occurrence, and applying to them the mathematical test of the least probable error, the number of observations being made dependent on their agreement among themselves. For each observation, the appearance of the signal observed has been noted, and the means have thus been obtained for a discussion of the results with reference to the condition of vision, from which it has appeared that the mean of observations, taken under various conditions of the atmosphere, is probably to be preferred to the mean of such as have been obtained under apparently the most favourable circumstances; the corrections required to fulfil the geometrical conditions of the work being less in the former case, while a given limit of probable error can generally be reached in much less time. This result may be readily accounted for by supposing that under apparently the best condition of vision along a line, a slight lateral deflection may regularly take place, which is eliminated in the mean of observations taken under different conditions of the atmosphere.

The average correction to an observed angle required in the eastern section, where the stations are on natural elevations, and the sides average over 40 miles, is about $0''\cdot4$. In the southern sections it is rather larger. The limit of error allowed in a primary triangle is one second to an angle; this, however, is seldom reached in fact.

Observations of Latitude, and the Apparatus.—Observations of *latitude* are made at numerous stations of the primary triangulation. Different methods and

instruments have been used, and the results have been carefully discussed, to determine which are the best and most available. A 2-foot vertical circle and some 12-inch repeating reflecting circles, by Troughton and Simms, 6-inch and 10-inch repeating theodolites, by Gambey, were tried successfully, but the results were found to be liable to considerable instrumental errors, and their accuracy did not repay the labour bestowed on them. Finding that instruments of a larger class were requisite, Mr. Bache procured from Mr. Simms a transit instrument, a zenith telescope, made on Captain Talcott's plan, and a zenith sector, according to Mr. Airy's design, each of the instruments having a telescope of 45 inches focal length. They were compared by observations made with each at the same stations.

The *transit* mounted in the *prime vertical* gave very satisfactory results, but its use was abandoned on account of their paucity, corresponding sets of eastern and western transits being rarely obtained on account of the cloudiness of the sky.

The *zenith telescope*, or equal altitude instrument, is a great favourite as a field instrument among American observers, although but little known in Europe. Its use consists in measuring with a micrometer the differences of zenith distance of stars culminating at nearly the same altitude, on different sides of the zenith, within a short time of each other. The British Association's Catalogue furnishes any desirable number of pairs of stars having the required relative positions. The observations with the zenith telescope being considerably more accurate than the north polar distances of the stars in the catalogue, the number of pairs of stars used has been increased, rather than the number of observations on the single pairs. In practice, from 25 to 40 pairs of stars are observed at a station, with three or four observations on each pair on different nights. The average probable error of a north polar distance in the British Association's Catalogue is $1''.7$, while the probable error of an observation with one of the zenith telescopes, as constructed by Simms, is about $0''.5$. The recent Greenwich Twelve Years' Catalogue frequently supplies

better places of the stars, and this contributes to improve the result.

A new zenith telescope, constructed recently by Mr. Würdemann, of Washington City, on an improved plan, has been found to give results with a much less probable error than the former instruments.

For further details concerning this valuable instrument, see "Notes on the Zenith Telescope," by Professor Bache.*

The *zenith sector* of the Coast Survey is constructed on the plan communicated by Mr. Airy in the Notices of the Astronomical Society.

It is regarded by the American surveyors as an admirable instrument, and its results are considered to have about the same accuracy as those of the zenith telescope: its ponderousness, however, and the greater laboriousness of the observations, make it less desirable as a field instrument than the latter. Its capabilities, however, are far greater than those of the zenith telescope, as it measures absolute zenith distances, and it is used for determining corrections to the catalogue of north polar distances of stars observed at different stations with the zenith telescope.

When the latitudes observed at different stations are referred to one another by means of the geodetic differences of latitudes, there appear discrepancies much larger than could result from the residual probable error of observation, which can only be ascribed to local irregularities in the figure and density of the earth, and which are designated as *station errors*. They are similar to those caused by the proximity of mountains, but occur where the external configuration of the earth's crust would not indicate their existence. Mr. Bache recognized this source of error in 1844, and as a consequence, determined to carry on a continuous series of astronomical stations through the primary triangulation, in order to arrive as nearly as possible at the true figure of the portion of the earth's surface he was engaged upon.

* American Journal of Science and Arts. Second Series. Vol. XIV. 1852.

The elements of the figure of the earth, used in these comparisons, are those obtained by *Bessel* in his last discussion of the results of ten measured arcs. It is interesting to know, that the observed difference of latitude of the extremities of the arc at present passed over by a connected triangulation agrees very closely with the geodetic difference computed on *Bessel's* elements. This arc extends from Maine to Maryland, over about 5 degrees of latitude and $6\frac{1}{2}$ degrees of longitude. In intermediate portions of this arc, the deviation from the mean ellipsoid reaches three seconds of arc and over, but without any regularity, inter-visible stations differing frequently with opposite signs. The average amount of station error is between one and two seconds of arc in the eastern portion of the survey, and about half a second in the sections south of the Delaware.

Azimuth Observations.—Observations of *azimuth* are made at all the latitude stations. The instruments employed are the same that are used for the angles of the primary triangulation. The meridian is determined by observations on the pole-star, principally near its greatest elongations, where the result will be nearly independent of the knowledge of time, the star having very little motion in azimuth, and when observations taken within 45 minutes on either side of the elongation can be reduced to that position of the star by a most simple formula. The pole-star, however, moves so slowly in azimuth, even at its culminations, that the liability to error in pointing is found to be no greater at those periods than at elongations; and Mr. Bache has occasionally pursued the plan of observing on the star at equidistant times on both sides of the meridian near the culmination. In these cases the reduction is simplified into a mere taking of means; and it may be noticed, that here, as in every other process, it has been the aim of the Superintendent so to arrange the method of observing as to diminish, as far as practicable, the labour and liability to error of the computation.

The azimuths are liable to the same irregularities which affect the latitudes from local variations of level; and a comparison of azimuth observed at inter-visible

stations has shown the station errors to exist in the same measure as exhibited by the latitudes.

Instruments used in observing local time.—Observations of local time are made in connection with those of latitude and azimuth, the instruments employed being generally portable transits of from 26 to 48 inches focal length, constructed by Simms of London, and Würdemann of Washington. Chronometers by the best makers are used in preference to clocks (except for telegraphic determinations of longitude), on account of their greater portability and the half-seconds beat.

Observations of Longitude.—In order to fix American *longitude* in reference to European observations, observations of eclipses, occultations, and moon culminations, made at different American observatories previous to 1844, as well as the corresponding observations at European observatories, have been collected and reduced; and similar observations have since been continued at Cambridge in Massachusetts, Philadelphia, Washington, Charleston, and Cincinnati. All these stations being connected by the electric telegraph, their differences of longitude have been determined with great accuracy, and all the results are referred to Cambridge as a common station of reference.

The difference of longitude between Cambridge and Liverpool has also been determined by means of a large number of chronometers carried repeatedly between the two stations on the Cunard's steam-ships. This work is still in progress, and the intention is to accumulate so large a number of chronometric results, as to be entitled to the same confidence as that obtained from observations of the moon. It is remarkable, that while the results from occultations differ sensibly from those obtained by moon culminations, the chronometric results differ again from both, and by an amount which a larger number of results is not likely materially to diminish. It remains to be seen whether the recent corrections of the lunar theory will so modify the results depending on the moon as to produce a better agreement. For an interesting numerical comparison of these results, see Appendix, No. 26, of the Annual Report for 1851.

The differences of longitude between Cambridge

and principal stations of the survey in other sections are determined by the aid of the electric telegraph, where the latter has extended. The manner in which the difference of longitude is obtained may be briefly stated as follows:—Transit instruments are mounted at both stations; at one of them an astronomical clock makes a record of its seconds beats on a sheet of paper, by breaking a galvanic circuit which passes through both stations each time the pendulum passes the vertical; the times of a star's crossing the wires of the transit at each station are recorded on the same sheet by the observer's breaking the circuit by pressing a key the instant the star appears bisected on the wire. The passages of the same star over two different meridians are thus recorded by the same timepiece, and the difference of longitude results immediately after applying the necessary instrumental corrections.

The method of recording observed instants of time by means of an electro-magnet on a time-scale graduated by a clock, designated by Mr. Airy as the American method, and its application to the problem of telegraphic differences of longitude is due to the late Mr. S. C. Walker, one of the assistants on the coast survey, to whom Mr. Bache had entrusted the charge of the longitude department. The mechanical detail of the apparatus employed was furnished by others; and, indeed, several different modes have been devised; but it was Mr. Walker who designed the new plan, and pointed out what mechanical conditions were required to be fulfilled to attain the end in view.

In the course of these telegraphic operations, it became apparent to Mr. Walker that a far more suitable time was required for the transmission of the galvanic current through the telegraphic wires than had been generally supposed. A number of experiments made on different lines to investigate this subject showed that the velocity is between 15,000 and 16,000 miles in a second. For an interesting discussion of these experiments, giving a detailed description of the apparatus, see a paper by Dr. Gould, on the Velocity of the Galvanic Current in Telegraph Wires, in Appendix No. 25 to the Annual Report for 1851.

By means of the electro-magnetic register and telegraph, differences of longitude are determined with an accuracy nearly approaching that of the latitudes, and arcs of parallels may be measured with the same facility as arcs of the meridian.

In sections where the telegraph has not reached, as Florida, the shores of the Gulf of Mexico, and the Pacific coast, the longitudes of cardinal points are determined by observations of moon culminations and by chronometers. Corresponding observations of moon culminations are made at several American observatories, at the expense of the Coast Survey, and valuable aid is derived from the series of meridian observations of the moon made at Greenwich. The promptitude with which these have been always supplied through the kindness of the Astronomer Royal, Mr. Airy, is gratefully acknowledged by Professor Bache, and both he and his colleagues express their admiration of the manner in which the reductions are made to keep pace with the observations at the British Observatory.

The late Mr. Walker bestowed great attention on the method of longitudes by moon culminations, and arranged the details of the reduction in an admirable manner. The recent improvements in the lunar theory lead to the hope that the moon's right ascension for any given time may be represented more accurately by theory than by any single observation, in which case corresponding observations would be dispensed with, and the reduction of the longitude effected in a much simpler plan, which has been developed by Professor Pierce, of Cambridge. Extensive computations are actually in progress under the direction of the Superintendent, having for their object to test theory by observation, and to produce corrected lunar tables.

Observations of *magnetic declination*, *dip*, and *intensity* are made at all astronomical stations, and at many other points where it is desirable to know the declination for purposes of navigation. The instruments employed are similar to those used in the British magnetic surveys, being declinometers and horizontal force magnetometers on the plans of Gauss and Weber, Lloyd, and Lamont, by Jones of London, and dip-

circles by Barrow and Gambey, provided with Lloyd needles for total intensity. In this manner not only the variation of the compass required for the mariner is obtained, but also contributions to our knowledge of the earth's magnetism, the value of which can hardly be appreciated as yet.

Observations on Heights.—The heights of the trigonometrical stations above the level of the sea are determined generally by observations of reciprocal zenith distances, frequently checked by direct levellings from the ocean. Interesting observations are in progress to compare results obtained by these methods with barometric and thermometric measurements of heights.

The Topographical Survey.—The topographical survey is executed with the plane-table on scales of $\frac{1}{5000}$, $\frac{1}{10000}$, and $\frac{1}{20000}$ of nature, according to the importance of the locality and the amount of detail to be represented. On the sheets drawn in the field the irregularities of the surface, hills, and depressions are indicated by horizontal curves, drawn at certain fixed vertical distances from each other. In the reduced drawing for the engraved charts, the spaces between these horizontals are filled up with *hashures*, the shade being darker in proportion to the steepness of the slope, according to a system somewhat modified from that of Lehman. Scales of shades showing the distance between the hashures, and the strength adapted to different scales of the maps, have been printed. The absence of very steep slopes and predominance of small ones rendered necessary the modification of the Lehman system.

The topographical survey is carried inland as far as required for purposes of navigation and the defence of the coast.

The Hydrographical Survey and Charts.—The hydrography is next in order. Soundings are taken with such frequency, as to exhibit the configuration of the bottom with sufficient minuteness for the purposes of navigation, the number of casts depending on the greater or less irregularity and slope of the bottom. The positions of the casts are determined in reference to the trigonometrical stations, generally by means of angles measured

with the sextant at the place of sounding, and sometimes by the use of theodolites at two shore-stations; the latter especially in off-shore work, and in cases where great accuracy is desired. Great aid is also derived from the outlines of the topographical survey in fixing positions, as well as in determining the *lines of equal depth*, which are drawn on the charts for every fathom down to three or four fathoms.

The spaces contained within the several *fathom curves* are shaded by dotting, lighter shades corresponding to greater depths. The configuration of the bottom is thus graphically represented to the eye, and the direction and limits of channels are conveyed to the mind in a more rapid and comprehensive manner by mere inspection, than could be done by a close examination of the figures indicating the depths, which of course are also given.

Soundings.—The soundings extend from the shore and the head of tide-water generally, out to sea as far as soundings can be of use to navigators in determining their position. In this point of view, not only the depth, but also the character of the bottom, is of importance: the sounding-leads are provided with an apparatus to bring up a portion of the bottom, specimens of which are deposited in the archives of the Coast Survey. Microscopic examinations of some of the specimens from considerable depths have shown them to be crowded with organisms, the number and genera varying with the depth; and it is not impossible that science may here supply the mariner with another mode of determining his position at sea.

Discoveries by the Hydrographic Survey.—It is the hydrographical department of the survey that develops the results to which public attention are most directed, and which most immediately benefit the community. By the thorough system of hydrographic survey, new channels are discovered and hidden dangers are pointed out; the positions of many that are imperfectly known are determined with accuracy, and the proper positions for buoys, beacons, and light-houses are indicated. Among the benefits thus conferred upon commerce, we may enumerate the discovery of a new channel, straighter

and deeper than those before known, over the outer bars of New York harbour; of several channels into Delaware Bay, and of one inside the bay, often free from ice when the main channel is obstructed; of channels across the Cape Fear Shoals; of a new channel into Key West Harbour, and one of an increased depth, into Mobile Bay. The discovery and accurate delineation of Davis' Shoal and of Davis' Bank off Nantucket, and of other shoals in the vicinity, in the track of the commerce between New York and Europe, have been of the greatest value. Numerous harbours of refuge along the coast have been sounded out, and charts with sailing directions have been, for the first time, furnished to navigators.

Observations on Tides.—The subject of *tides* is receiving great attention, not only with reference to local tides and currents, but the general laws of the phenomena, both on the Atlantic and Pacific coasts, are under discussion. Extensive half-hourly observations of the tides have been made at a number of stations, extending over a time of from one to three years; at intermediate points, half-hourly observations during two lunations are found sufficient to exhibit the law and constants. Within a year or two past, self-registering tide-gauges have been used with excellent success. Professor Bache personally engages in the discussion of this most interesting subject, and has made several communications to the American Association for the Advancement of Science, on the nature of these researches and their results, which will be found in their Transactions.

This subject is the more important, since the tides of the Atlantic, Pacific, and Mexican Gulf coasts of the United States present three distinct types; the diurnal tide, which is moderately large on the Atlantic coast, producing a perceptible diurnal inequality in height and time,—is very great on the Pacific,—and almost obliterates the semi-diurnal tide in the Gulf of Mexico.

The direction and velocity of tidal currents, as important to navigators as the rise and fall of the water, are also observed with care. Tide and current tables on the charts embody the information thus obtained, and convey to the mariner all the knowledge he requires

of the times, heights, and durations of tides, and the set and drift of currents.

Exploration of the Gulf Stream.—In connection with the hydrography, the present Superintendent has undertaken the *exploration of the Gulf Stream*. The plan of exploration is to determine the temperature and other physical circumstances, at different depths from the surface to the bottom, at positions on lines perpendicular to the axis of the stream, drawn from capes and headlands of the coast at suitable distances from each other. In this way various sections of the stream have been made, beginning north at Cape Cod in Massachusetts, and extending south to Cape Canaveral in Florida. The cold current between the coast and the Gulf Stream, the two branches into which the stream divides south of Hatteras, and the cold water between, and the ocean beyond to a sufficient distance from the warm water of the gulf, have been thus examined. On the section across the stream from Charleston, bottom was had at less than 500 fathoms in every cast, and a bank has been discovered and traced on the east side of the stream from the Charleston to the Canaveral section. This work is still in active progress, and it is much to be desired that the exploration eastward, from the American side of the northern part of the stream, should be met by a corresponding exploration from the shores of Great Britain westward, which would complete our knowledge of the Gulf Stream throughout its whole extent from the shores of Florida to those of Ireland.

Survey of the Pacific Coast of the United States.—Within a few years past the Pacific coast of the United States suddenly assumed a great importance in a commercial point of view. Its geography was very imperfect, and great inconvenience arose to navigators from the want of reliable charts. Professor Bache with great energy immediately extended the survey to that new region. The wants of commerce required a rapid survey of the whole extent of the coast, the geographical positions of the principal headlands, lines of sounding to show how near the land might be approached, and examinations of the entrances of harbours of commerce and refuge. The more elaborate and accurate, but

necessarily slow, system which we have detailed must for a time be set aside, and reconnaissance work must take the place of the refined survey. The most necessary results were furnished to the world in a surprisingly short time. This is a field where discoveries are made at every step, and to enumerate them would be to rehearse the whole of the work done.

Reduction and Publication of the Observations by the Survey.—The results of the field-work are prepared for publication at the office of the Coast Survey in Washington city. The reductions of geodetic and astronomical observations are in the first instance made by the observers themselves, and a second computation is made independently by persons having no connection with the field-work. A strict scrutiny of the observations and perfect security against errors of computation is thus ensured, the two computations being examined and compared by an experienced person, who refers discrepancies which may occur to the Superintendent. The records of observations and computations are also put in form for publication.

The Annual Report of the Superintendent for 1851 contains a table of over 3000 geographical positions of trigonometrical points determined by the coast survey.

Execution and Publication of the Charts and Maps.—The original sheets, containing the topographical and hydrographical work, are combined and reduced to the scale of publication by regular draughtsmen in the office. The beauty and accuracy of these drawings can scarcely be surpassed.

The maps and charts are of three classes,—charts of harbours, maps of portions of the coast, and sketches of discoveries, &c. The scales of publication vary from $\frac{1}{10000}$ to $\frac{1}{400000}$, according to the detail to be represented.

The charts are engraved on copper by a corps of engravers in the office, among whom are some first-rate artists. When ready for publication, the plates are multiplied by the electrotpe process; the originals are preserved in the archives, and the electrotpe copies are used in printing. For an interesting description of the electrotyping process, as carried on at the office of the

Coast Survey, see Appendix No. 55 of the Annual Report of the Superintendent for 1851. Large charts are sometimes engraved in two or four separate pieces, and then joined on a common electrotypes plate; by this means great despatch may be effected, as several engravers can be engaged on the chart at the same time.

The prices at which the charts are sold are extremely low, ranging from fifteen cents to one dollar. They are freely distributed to all educational institutions, libraries, &c.

In conclusion it may be observed that the funds for carrying on the survey are voted annually by Congress, upon estimates submitted by the Superintendent, and the work above sketched out is executed in a manner as economical as it is accurate and comprehensive.

Exhibited Articles.—The following list embraces the contributions by the Bureau of the Coast Survey of the Treasury Department of the United States to the Exhibition in New York:—

- Nos. 1. Base-line apparatus for laying down the base-line in geodetic trigonometry.
2. Astronomical transit instrument.
3. Astronomical zenith telescope.
4. Half-inch theodolite, for primary triangulations.
5. Heliostat.
6. Horizontal sectors for secondary triangulation.
7. Plane-table and metre-chain.
8. Sextants used in hydrography.
9. Steelwagen's sounding-lead, and specimens of ocean bottom.
10. Saxton's deep-sea thermometer.
11. Sphere crushed by the pressure of deep sea.
12. Sexton's reflecting pyrometer.
13. Electrotypes, comprising model plates, and their electrotypes moulds and duplicates.
14. Electrotypes copper, exhibiting great hardness, elasticity, and soundness.
15. Hydrographic and plane-table sheets.
16. Maps and charts of the United States' Coast Survey, and progress sketches.
17. Reductions for engravings.
18. Self-registering tide-gauge.

Natural History Charts.— Besides the “Whale Charts,” by Lieutenant Maury, to be noticed presently, a coloured map or chart, executed by James D. Dana, A.M., was exhibited, in which the geographical distribution of marine animals, especially that of the different species of crustacea, is explained. This chart, a work of great originality, gives in one view the results of multiplied observations. It accompanies a report by Mr. Dana, made to the Government of the United States, on the Crustacea collected during the Exploring Expedition under the command of Captain Wilkes, U. S. N., during the years 1838-1842.

The author has laid down on his map the isocrymal lines on the zones of greatest cold of the surface-waters of the ocean, in preference to the isothermals usually traced on maps descriptive of climate, since he finds that they are of higher importance in limiting the range of marine species. These isocrymal lines are not precisely those of any chart previously constructed, for they mark the positions where a given temperature constitutes the mean of the coldest month of the year,—for example a zone where the coldest thirty consecutive days may be 68° or 50° or 35° , Fahrenheit, or some other given temperature. The geographical distribution of marine life is stated to be a subject of far greater simplicity than that of continental life and the lines which bound the coral-reef seas and the range of certain mollusca and radiata coincide with those which govern the distribution of the crustacea. Hence the subdivision of the frigid, temperate, and torrid zones adopted in this chart have a direct bearing on the general advancement of our knowledge of the geography of marine life.

Maury's Charts.—In this department the “Wind and Current Charts,” published by Lieutenant M. F. Maury, U. S. N., Superintendent of the National Observatory at Washington, occupy a prominent place, both as regards their usefulness and the novelty of the information which they convey. It was in 1842, that Lieut. Maury conceived the idea of requiring all the masters of American vessels to keep their log-books in an improved form, so as to exhibit, in addition to the ordinary information, records of all phenomena that could be rendered avail-

able for the improvement of hydrography and navigation, and generally for the promotion of science; and of employing the materials so recorded for constructing improved charts, to be engraved at the expense of Government, and distributed, free of cost, to those captains who supplied the data for their construction, or who sent to him what he terms "abstract logs." Lieutenant Maury applied to the United States Hydrographer, who entered warmly into the scheme; and circulars, addressed by the latter to all masters of vessels, were placed in the hands of the collectors of customs, who had instructions to give a copy to every captain at the time of clearance.

For some time this measure produced no fruit, but Lieutenant Maury persevered, and having obtained several old log-books from the Navy, and diligently studied and collated them, he discovered the existence of a shorter route to Rio; which discovery he publicly announced in 1848. Vessels which tried this new route reached the line, on an average, in nineteen days, whereas the same distance had previously taken them about forty days. The success of this experiment immediately caused the whole scheme to be regarded with favour,—abstract logs came in in abundance, and in 1853 more than 1000 masters of vessels were engaged night and day in making and recording the observations required; their logs are carried to the Observatory, where the information they contain is collated and entered on charts, and the results to the latest period are published in successive editions of Maury's "Sailing Directions." In some of the Wind and Current Charts the course of the trade-wind is laid down, as also the isothermal lines traversing the ocean.

Besides the charts by Lieutenant Maury already mentioned, others by the same author were exhibited, called "Whale Charts," in which the principal statistics of the whale fishery are given in the form of maps; especially the number of different species of large cetaceans found to occur in the ocean north and south of the equator.

Lord Wrottesley, in an able speech delivered in the British House of Peers (April 26, 1853), gave a full and clear explanation of Lieutenant Maury's plan for improving navigation and for promoting meteorological science.

At the same time he earnestly advocated a proposal, previously made by the Royal Society of London, that the British Government should co-operate with the United States "by furnishing every ship under the control of the Admiralty with instruments properly constructed and compared, and with proper instructions for using them."

It is satisfactory to record that in the month of July, while the British Commissioners were yet in the United States, a meeting of the leading merchants of New York, representing more especially the shipping interest, took place, in which a public acknowledgment was made of the services rendered by Lieutenant Maury to his country. At the same time a valuable testimonial was voted to him, in proof of the high appreciation entertained of the results of his patient and skilfully directed labours.

At the Brussels Congress also, presently to be noticed, a vote of thanks was passed to Lieutenant Maury; and similar acknowledgments were subsequently made to him at public meetings of merchants and shipowners in London and Liverpool.

In August and September, 1853, a scientific congress was held at Brussels, to which the chief maritime nations of Europe sent delegates for the express purpose of consulting with the American hydrographer, and concerting with him a plan of combined operations, whereby the physical features and meteorology of the ocean might best be explored, and a record kept of scientific observations, calculated to promote the progress of navigation. The nations represented at the "Maritime Conference" were Belgium, Denmark, France, Great Britain, the Netherlands, Norway, Portugal, Russia, Sweden, and the United States. This meeting was convened at the suggestion of the American Government, consequent upon a proposition which it had previously made to the British Government, (in reply to a desire which had been expressed on the part of Great Britain that America should join in a uniform system of meteorological observation *on land*,) for extending Lieutenant Maury's plan of research. Although difficulties were at present found to exist with regard to the desired *uniformity* of the methods of observation *on land*, it was proposed that meteorological observations should be made by the military and

mercantile marine, British and American, as well as by the mariners of all civilized nations, as far as possible, in a uniform manner over all navigated seas.

Meteorological observations* to a certain extent had long been made at sea, and Lieutenant Maury had turned to useful account such as had from time to time fallen into his hands; but these observations, although many of them good in themselves, were but isolated facts, deprived of much of their value from the absence of observations with which they could be compared, and above all from the want of a constant and uniform system of record, and from the rudeness of the instruments with which they had been made. The moment then appeared to him to have arrived when nations might be induced to combine in a general system of meteorological research. To use his own words, he was of opinion that "the navies of all maritime nations should co-operate, and make these observations in such a manner and with such means and implements, that the system might be uniform, and the observations made on board one public ship be readily referred to and compared with those made on board all other public ships, in whatever part of the world. And, moreover, as it is desirable to enlist the voluntary co-operation of the commercial marine, as well as that of the military of all nations, in this system of research, it becomes not only proper, but politic, that the forms of the abstract-log to be used, the description of the instruments to be employed, the things to be observed, with the manipulations of the instruments, and the methods and modes of observation, should be the joint work of the principal parties concerned."

The Conference opened its proceedings† at Brussels on the 23rd August, 1853, and was attended by twelve eminent meteorologists, hydrographers, and engineer officers, naval and military, selected by the respective Governments before mentioned. The United States were represented by Lieutenant Maury, the talented and indefatigable originator of this admirable scheme for improving navigation and advancing the progress of science; and

* Maury's Sailing Directions, p. 55, 6th ed., January, 1854.

† Ibid., p. 54, &c.

M. Quetelet, the renowned Belgian meteorologist, presided at the meetings.

In concerting a plan of uniform observations for all nations, the Conference took into consideration the inconvenience arising from the variety of scales in use in different countries. After mature deliberation, no modification was recommended, except with regard to thermometers; it being agreed that the centigrade scale should be used in addition to the one employed, whether Fahrenheit or Réaumur, with a view to its ultimate general adoption.

The *accuracy* of the barometers and thermometers used, their comparison with standards, and the correct ascertainment of the errors of the instruments, were insisted upon. The mercurial barometer was preferred; and the attention of the public was directed to the *desideratum* of an economical marine barometer, that, at all times and in all weathers at sea, would afford the means of absolute and accurate determinations.

An anemometer also was considered necessary for the contemplated plan of research.

For the more complete observations, thermometers with dry, with wet, and with coloured bulbs are required. In addition to the implements above mentioned, and those generally used at sea, the only other instrument with which the Conference recommended the ships be provided was one of trifling cost, for obtaining the specific gravity of sea-waters.

The object of the Conference being to secure, as far as possible, uniformity of record, and such a disposition of the observations, that they would admit of ready comparison, a certain form of register was concerted and agreed upon. The first columns of this form will receive the data which the Government of the United States require merchant vessels to supply, in order to entitle them to the privileges of co-operators in this system of research, and may therefore be considered as the *minimum* of what is expected of them. This condition requires that at least the position of the vessel, and the set of the current, the height of the barometer, the temperature of the air and water, should each be determined once a-day; the force and direction of the wind

three times a-day; and the observed variation of the needle occasionally. The register contains other columns that are intended for men-of-war to fill up, and for such officers in the mercantile navy as may be willing to distinguish themselves in this joint action for the mutual benefit of the services.

A concise body of instructions for making certain observations and filling-up the columns of the register (or of the abstract-log, in the case of merchantmen) were drawn up by the Conference. The directions were limited to such only as seemed necessary to insure uniformity of observation.

The Conference also expressed a hope that whatever observations may be made will be turned to useful account without delay; and that, with this view, the several Governments will individually and mutually give their best attention to the means for perfecting the discussion and reduction of the observations obtained, and the interchange of materials and results.

General support of the plan of Universal Observation.
—Lieutenant Maury has notified, that, with regard to the proposals that have emanated from the United States for a universal system of meteorological observation by sea and land, he has received assurances of approbation, support, and co-operation from very many sources, including scientific individuals and societies at Bombay, Calcutta, Mauritius, &c.; and in England and on the Continent; also from the Holy See, Sardinia, Holland, Prussia, Spain, Brazil, Peru, New Grenada, Chili, &c. With respect to the definite object of the Brussels Conference, namely, the adoption of a uniform system of observations by the marine of all maritime nations, the Report refers to the measures already taken by the Governments of Sweden and Norway, the Netherlands, Belgium, and Portugal, towards the establishment of a department for the object in view, and notifies that the Admiralty of Great Britain has expressed its intention of giving instructions for meteorological observations to be made throughout the Royal Navy.

Thus much we learn from Lieutenant Maury's published Report of the progress of the system so happily suggested by himself, and so warmly supported by various

public and private coadjutors. With reference to the active part which the British Government is about to take in the furtherance of Lieutenant Maury's comprehensive and useful plan, it is arranged that a Parliamentary grant be made this year to the Board of Trade, *Department of Science and Art*, for carrying out the meteorological observations at sea, and for establishing an office for their discussion. This office will be located at Marlborough House, the officer in charge of it being a well-qualified captain in the Navy. By the co-operation of the departments of the Board of Trade, (that of Science and Art, and that of Mercantile Marine), ships will be provided with instruments at the public cost; these instruments being carefully compared with standards at the Kew Observatory, under the direction of the meteorological committee of the British Association, which has recommended the particular instruments that are to be used. Under these favourable auspices, and with the support of a widely spread and well-organized body of observers, actuated in their work both by public and private interests and by the love of science, Lieutenant Maury's noble plan for the study of oceanic meteorology, the benefit of navigation, and the general advancement of science, bids fair to fulfil the most sanguine hopes of its originator.

